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PRINCIPAL INVESTIGATOR: Dr. Dexter G. Smith

CONTRACTING ORGANIZATION: The Johns Hopkins University
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Smith, Dexter; Cutchis, Protogoras; Wiesmann, William; Pranger, Alex; Denney, Teresa

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The objective of this cooperative agreement was to develop the concept and a specification for a Far Forward Life Support System (FFLSS) that enables medic/corpsman first responders to provide on-scene critical life-saving support during the crucial minutes after a combat casualty and during evacuation. The FFLSS is a patient ventilator integrated with state-of-the-art commercial-off-the-shelf (COTS) physiologic sensors and a digitally-controlled feedback system for automated monitoring and regulation.

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FOREWORD

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_______ In conducting research utilizing recombinant DNA technology, the investigators adhered to current guidelines promulgated by the National Institutes of Health.

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_______ In the conduct of research involving hazardous organisms, the investigators adhered to the CDC-NIH Guide for Biosafety in Microbiological and Biomedical Laboratories.

Dexter G. Smith 27 Aug 98

Dr. Dexter G. Smith, Principal Investigator (date)

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1 Introduction

1.1 Objective

This objective of this cooperative agreement was to develop the concept and a specification for a Far Forward Life Support System (FFLSS) that enables medic/corpsman first responders to provide on-scene critical life-saving support during the crucial minutes after a combat casualty and during evacuation. The FFLSS is a patient ventilator integrated with state-of-the-art commercial-off-the-shelf (COTS) physiologic sensors and a digitally controlled feedback system for automated monitoring and regulation.

1.2 Purpose and Scope of Cooperative Agreement

The purpose of the cooperative agreement was to be the first phase of a three phase process to develop, fabricate, and test a new battlefield patient ventilator system. This phase developed the concept and specification for the device. Phase II would fabricate a prototype. Phase III would test the device on animal and human subjects. The original period of performance, September 1997 through March 1998, was extended to 31 August 1998.

1.3 Background of Previous Work

Since 1965, The Johns Hopkins University Applied Physics Laboratory (JHU/APL) scientists and engineers have collaborated with faculty of The Johns Hopkins Medical Institutions to solve significant problems in biomedicine and health care delivery. More than 100 specialized medical devices have been developed, including implantable medication-dispensing systems, rechargeable pacemakers, and opthalmological instruments. An ingestible temperature "pill" developed for NASA transmits core body temperature and other vital data to a remote monitor. JHU/APL is also applying advances in computing and communications technology to medical informatics and health care. JHU/APL staff demonstrated a telemedicine capability for Navy ships at sea, using low-cost, low-bandwidth commercial devices to link the medical personnel at remote sites and allow vital data exchange.

BioSTAR scientists and engineers participated in the invention and design of the original Life Support for Trauma and Transport (LSTAT™), a larger version of the FFLSS design. Experience gained in the design, development, documentation, and doctrinal enhancements of the LSTAT™ have been valuable links to the successful design of the FFLSS system.

2 FFLLS Concept

2.1 Assumptions

The basic assumptions for the FFLSS concept were based on doctrinal shifts that have occurred in the U.S. military since the end of the Cold War. These shifts place greater reliance on rapidly deployable, mobile, small footprint, advanced medical resuscitation capabilities that can be moved with forces deployed on the battlefield in a timeframe consistent with life-saving capabilities. The emphasis is to empower and enhance the medic's performance in the early minutes after acute traumatic injury, where medical intervention is most valuable in reversing a potentially fatal condition.

The most significant database that has contributed to these product development assumptions and doctrinal shifts is the WEDMET database. This database, accrued during the Vietnam era, consists of 8,000 patient records and studies detailing trauma following penetrating and explosive injuries of soldiers deployed in Vietnam. The data, correlated with data from other militaries, suggests that the largest mortality rates occur in the prehospital environment where no physicians are present during the early minutes after injury. Furthermore, the data proposes that the most effective response to this aspect of the battlefield scenario is to empower medics with technological capabilities that can restore circulation, stem hemorrhage, and maintain an adequate respiratory function and oxygen delivery in acutely injured patients. Coupled with the realization that U.S. forces will be deployed in small units for short-term police actions and battle scenarios, where distances and travel may be extensive, mitigates rapid removal and transport of heavy, weight-intensive medical equipment and supplies.

Experiences following Desert Storm and other U.S. incursions during the past two years stressed the need for small, lightweight, portable life resuscitation platforms that can be carried with the troops and used by combat medics. The FFLSS concept was derived from these basic understandings of changes in doctrinal and medical shifts within the U.S. military. Consequently, the design objectives address portablility requirements; i.e. the units should be small, preferably less than 15 pounds, have a long shelf life, and be transportable aboard common battlefield vehicles. The device would be simple to operate and provide life-sustaining support for the most common battle injuries encountered in modern combat. More specifically, the unit should support injuries such as respiratory failure and paralysis from tension pneumothorax, hemorrhage, noxis, pulmonary damage due to pulmonary exposures, respiratory inhalation exposures, burn injuries, chemical or biological weapon injuries, and acute ventalthoric control for any other respiratory failure that may occur or be related to sedation, anesthesia or shock. Designers assumed that the instrument must be easily resupplied or disposable and that all of the capabilities necessary to operate this device would be self-contained within the device. Among these assumed capabilities are suction, monitoring, and ventilatory settings that would permit the medic to operate one device or several devices simultaneously.

The FFLSS must provide a patient ventilator for mechanical breathing assistance; a capnograph to monitor CO_2 for ventilation effectiveness; a pulse oximeter for measuring blood stream oxygen saturations; an electrocardiograph (ECG) to monitor cardiac performance; alarms; and a data recorder. The principal advantage of this critical care system is the integration and test of these state-of-the-art COTS physiologic sensor subsystems with a new digitally controlled feedback system. This system should permit automated monitoring and regulation of the ventilator's rate and volume to provide optimum care, stabilize the patient and minimize the factors leading to post-traumatic circulatory collapse or hypoxia. The FFLSS must be rugged, lightweight, portable, configurable to a variety of standard military vehicles and transports within standard first responder activities.

2.2 Procedures

JHU/APL and BioSTAR envisioned the FFLSS to meet a variety of operational requirements facing trauma care personnel. First, BioSTAR identified specific medical, military and civilian needs and developed the Far Forward Life Support System Requirements. JHU/APL surveyed the medical instrumentation community for information on potential subsystems. JHU/APL translated the operational requirements and ventilator subsystem analysis results into engineering specifications for the FFLSS design and developed a mockup of the concept to address issues such as size and weight.

2.2.1 FFLSS Requirements

The requirements for this instrument were derived from the experience of the senior scientist and president of BioSTAR, retired Director of Combat Casualty Care research for the Army and from documents derived from planning and strategies obtained from the Joint Chiefs of Staff Medical Readiness Section. Other requirements and documentation were obtained from the Combat Development Operation at the Marine Corps Combat Development Center, Department of Medical Combat Development at Quantico Marine Base, Quantico, Virginia; from the working task force convened by the U.S. Army and U. S. Navy on Far Forward Advanced Surgical Support; from doctrinal development of the J-4 Medical Requirements Section of the Joint Chiefs of Staff; from the director of Combat Casualty Care at Ft. Detrick; and from the director of the Division of Surgery and Surgical Research at the Walter Reed Army Institute of Research. Further requirements were also refined from conversations with the chief of Air Evacuation at Brook Hospital in San Antonio, Texas; the Joint Vision 21 Joint Chiefs of Staff document for medical readiness, and from the Office of the Director for Defense Research and Engineering, and the Office of the Assistant Secretary of the Army for Acquisition, Research and Development.

A major conceptual design review was held at JHU/APL on 2 December 97. In addition to BioSTAR, personnel attended from Ft. Detrick, Walter Reed, and Quantico.

A second minor review was held at Ft. Detrick on 7 July 98. The purpose of these meetings was to bound the requirements for the system. These discussions addressed the merits of proposed features and needs for the device from the battlefield perspective.

The consensus requirements for an effective FFLSS are summarized below.

1. The FFLSS should adapt to multiple transport and logistical scenarios including medic transport, armored transport, aviation systems and operate within the constraints imposed for far forward operations.

2. The FFLSS must be portable and lightweight (under 25 lb).

3. The FFLSS should be self-contained, with an autonomous architecture that provides a simple, low cost, first responder apparatus for initial patient data acquisition. As the system advances, the data gathered by the sensor system should allow digitally controlled optimized care to the patient.

4. The FFLSS should continuously record selected patient data and then provide that data to other medical care systems after the patient is transported to a field hospital or other similar location.

5. The FFLSS should remain self-contained and operational for a minimum of one hour with no additional power.

6. The FFLSS should provide a low-power, lightweight ventilator system. Future systems should provide an integrated controller capable of digitally controlling the pump and ventilator to optimize patient care.

7. The FFLSS should provide an integrated pulse oximeter to measure oxygen saturation in the blood stream. The data would provide feedback on the effectiveness of ventilation efforts or the patient's own respiration.

8. The FFLSS should integrate a capnograph to measure breathing effectiveness, endotracheal tube (ETT) placement, and hyperventilation controls.

9. The FFLSS should integrate an ECG monitoring system to measure cardiac function.

10. The FFLSS should integrate an infusion pump to deliver fluids into the patient to manage the effects of shock.

11. The FFLSS should provide a suction capability.

2.2.2 Engineering Specifications

The starting baseline specifications are seen in Table 1. These were from the original proposal and were presented at the 2 December 97 conceptual design review.

Table 1 Preliminary FFLSS Requirements

Item	Comments	Item	Comments
Overall		**Special Considerations**	
Size	1 ft^3	Nonflammable	
Weight	15 lb	CW Corrosion Resistant	
Production	$15,000/unit	Low Outgas	
Cost		Low Radar Cross Section	0 dB rel m^2
Operation Time	2 hr	Low Emissivity/Radiation	10^{-1} watts
Telemetry	On demand	**Platform**	
Operating Properties		Land Motor Vehicle	12 VDC
Temperature	-20°C to 70°C	Fixed Wing Aircraft	12 VDC
Vibration	0 to 20 g, 0 to 500 Hz	Rotary Aircraft	12 VDC
Pressure	10^{-1} to 2 ATM	Field Hospital	12 VDC; 120 VAC / 60 Hz
Isolation	Ground Plane & Patient	**Subsystem Requirements**	
Packaging Requirements		Ventilator	
Size	1 cm ft^3, 19" Rack Compatible	Adjustable	Rate (5-40), Tidal Vol. (400-1000 cc)
Construction	Double Insulated, Water Washdown, Accessible Battery Compartment, Optional Removable Lid	Modes	Assist/Control, Others TBD
Paint	Low Optical Reflectivity, Nonconducting	Interface	RS232, Baud Rate TBD
Functionality	360° Roll, Pitch, Yaw Functionality	Oximeter	
Interfaces		Accuracy	+/- 2%, Range 0 to 100%
LSTAT		Sample Rate	120 Samples/Second
Personal Data Monitor (PDM)		Sensor	Transcutaneous Optical
Communications	TBD	Interface	RS232
Mounts	19" Rack, Backpack, Seat Harness	ECG	
Data Acquisition and Protocol		Heart Rate	0-250 BPM
Features		Flags	Asystole, Lead-Off, Excessive Heart Rate
Date-Time		Waveform	12-Bit ECG @ 120 Samples/Second
Patient ID		Interface	RS232 @ 38.4-K Baud
Flags, Alarms		Capnograph	
Input Selections		Range	0 to100 mm Hg
Protocol	RS232 Compatible, 9600 Baud, 8 Bits, Error Detection & Correction	Accuracy	+/- 2 mm Hg (0-40 mm Hg) +/- 5% (41-70 mm Hg)
Compatibility / Certification		Resolution	1 mm Hg
LSTAT		Compensations	NO_2 O_2
EMI (UH-1, UH-60)			
FAA			
FDA			
C4I			

2.2.3 Applications and User Interface

The FFLSS unit will be designed for front-line use by field medics but will be flexible enough to continue operation during evacuation and at a Mobile Army Surgical Hospital (MASH) or DEPMED unit. The unit will have power and data output connectors so that it can use external power and data-handling facilities, if available. In addition, this will allow the transmitter system in the FFLSS to be turned off selectively during stealth operations or helicopter transport, when electromagnetic interference (EMI) problems are more likely. The FFLSS will be designed for minimal radiated and conducted EMI as well as having low susceptibility to external EMI.

The medical data and alarm transmissions made by the unit will be designed for compatibility with military frequency allocations and bandwidth requirements. In addition, as much as possible within these requirements and within power availability limitations, the unit will transmit all data in a high-speed burst model to make location of the injured individual difficult. The unit may also be designed to decide autonomously the quantity and format of data transmissions within preset design rules to keep transmissions to a minimum.

To simplify logistics planning, the FFLSS will use existing COTS equipment wherever possible. Phase II will produce the final prototype design while Phase III will be the animal and human testing. Following Phase III, a detailed logistics planning document can be developed based on the final design. It is anticipated that this design will find application in the commercial sector. This dual use will also contribute to the logistics requirements of the system.

3 System Concept Description

3.1 System Goals

The FFLSS is designed to be a compact, stand-alone, self-powered instrument system whose primary function is to provide continuous ventilatory support for a 1 hr period. Significant characteristics of the FFLSS follow, and correlate to the previously listed consensus requirements.

(a) Ventilator, functional displays and alarm
(b) Air handling apparatus that includes interconnection of a face mask or intubation device to a replaceable NBC filter
(c) IV fluids infusion pump with functional display and alarm
(d) User interface for inputs from external devices, input settings, power, alarm resets, and sensor calibrations
(e) Pulse oximeter sensor for monitoring oxygen saturation in blood stream

(f) Capnograph (cpn) sensor for monitoring effectiveness of ventilation in the lungs
(g) Blood pressure monitor (BP)
(h) Electrocardiogram (ECG) electrodes for monitoring
(i) Controller to sensor interface
(j) Data acquisition and recording system that will:

1. accept user inputs on patient identification, critical signs (e.g., Personal Data Monitor), trauma checklist, patient characteristics;
2. continuously record patient ventilatory data, sensor data, and freshly logged user inputs; and,
3. send data and messages to the communications bus, user displays, and alarms.

(k) Communications system that will transmit key patient and instrument status messages to remote locale on command.
(l) User Interface Display for viewing patient status, instrumentation status, and commands received from the casualty coordination.
(m) Alarms system that not only reports instrument dysfunction, but also when patient status is beyond the acceptable bounds as derived from decision aids or external command.
(n) Power systems to instruments, microprocessors, displays, and telemetry.
(o) Apparatus chamber for housekeeping of attachments and spares.
(p) Suction pump.

3.1.1 FFLSS Block Diagram

Figure 3.1.1-1 is a conceptual FFLSS block diagram that shows how the FFLSS will integrate state-of-the-art physiologic sensors with a new digitally controlled feedback system. This diagram incorporates changes suggested at the 2 December 1997 review.

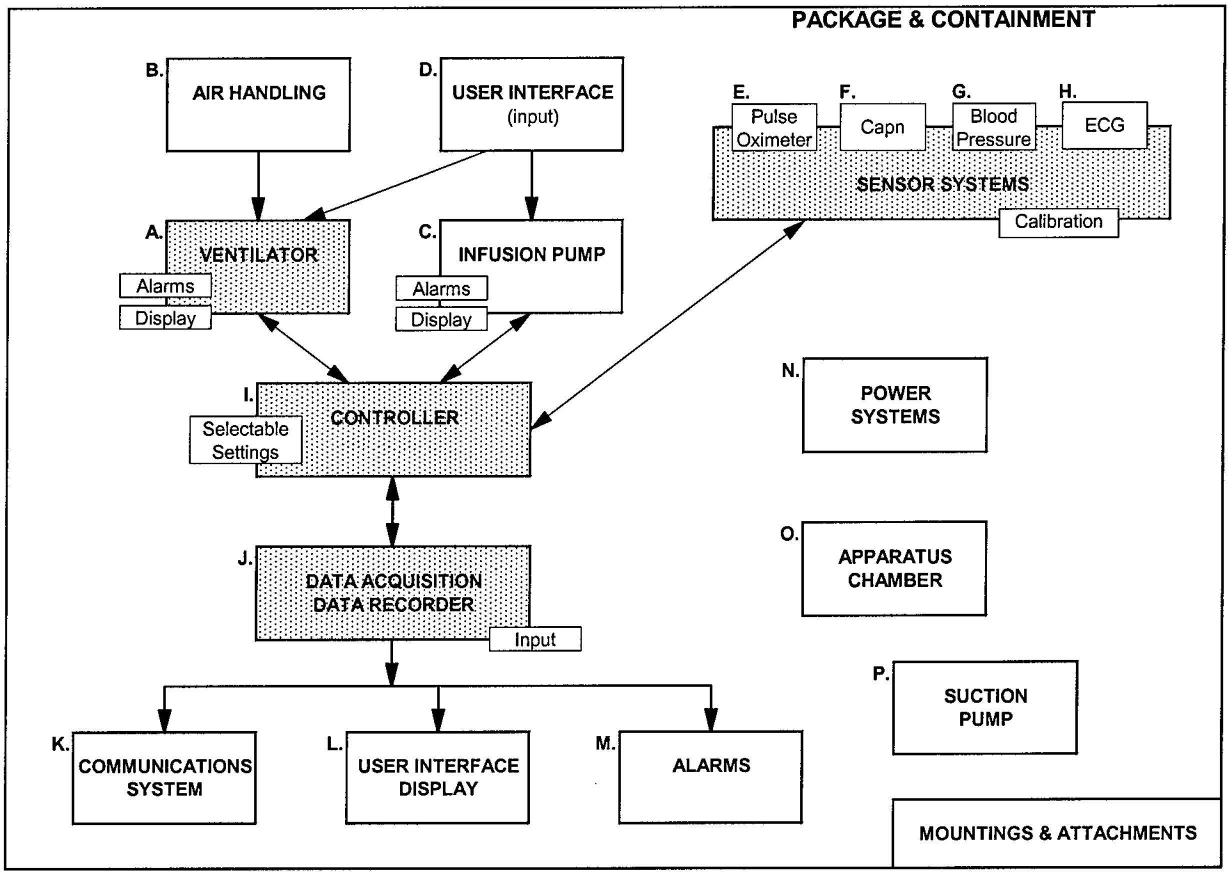


Figure 3.1.1-1 FFLSS Block Diagram

3.1.2 Ventilator Mockup Design

To fully understand the issues involved in designing a ventilator unit that meets the size and weight requirements, a mockup of the ventilator subsystem was fabricated. Off-the-shelf devices such as the ECG and pulse oximeter were not part of the mockup because their dimensions and functionality are well known.

Design Goals: The design goal of the prototype was to build a mockup that could ventilate for one half hour to an hour using internal battery power. Further goals were that the unit be made as small as possible and use the same or similar components to those that would be in the final FFLSS prototype. It was decided that to keep the size and complexity of the first prototype down either oxygen generators or associated thermoelectric generators would be incorporated. Lastly, it was a design goal to explore software features into the prototype that would demonstrate features and control algorithms either directly or indirectly applicable to the final unit.

Hardware Design: Figure 3.1.2-1 is a block diagram that shows the hardware configuration. The case chosen was a Pelican brand model 1400 that has outside dimensions of 13"L x 12"W x 6"D and inside dimensions of 12 1/4"L x 9 1/4"W x 5 1/4"D. In retrospect, this proved to be a very ambitious volume choice.

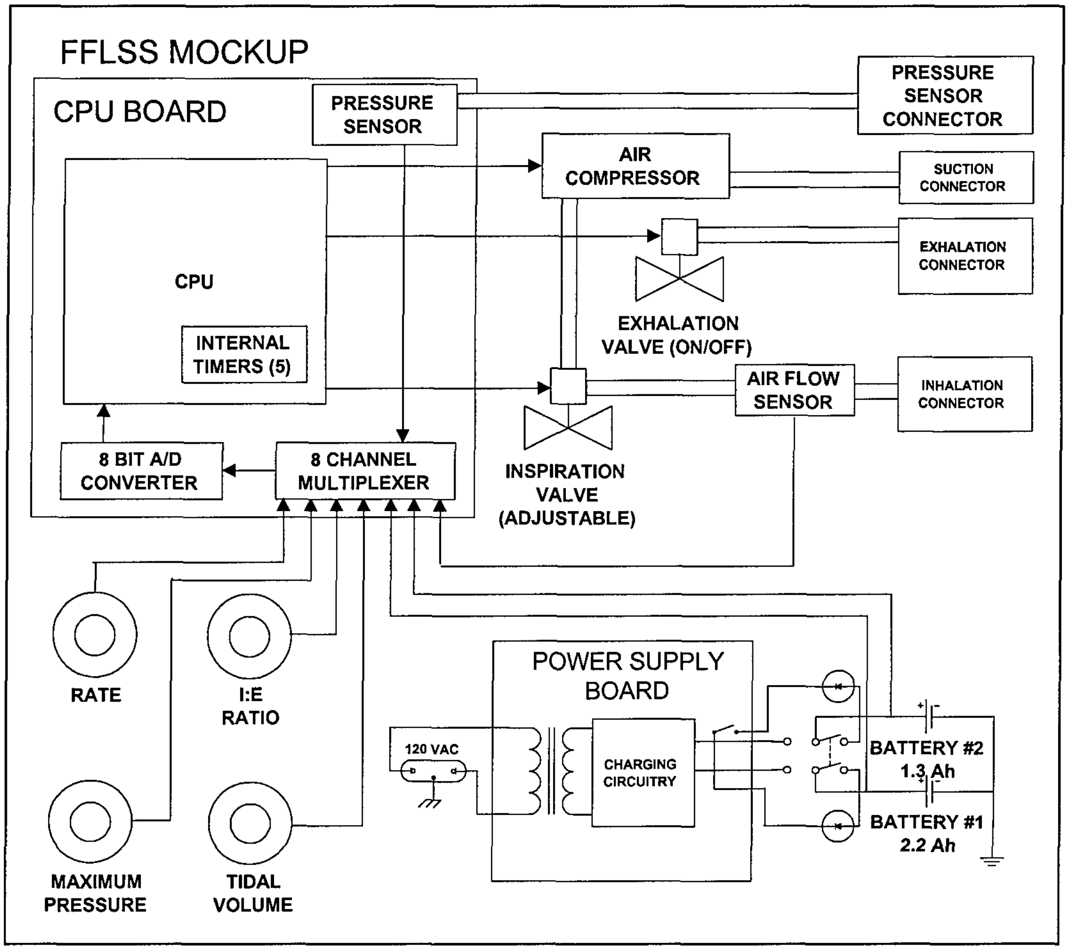


Figure 3.1.2-1 FFLSS Mockup

The system design centers around a compressor, several control valves, a power supply board, and a processor board based on a Motorola 69HC811 microprocessor. The four front panel adjustable parameters are the tidal volume (200 to 620 cc in 10-cc increments) respiratory rate (8 to 20 per minute), I:E ratio (1:1 to 1:3.0 in steps of 1:0.1), and maximum inhalation pressure (10 to 40 mm Hg in steps of 1-mm Hg). The maximum pressure is also determined by an adjustable pop-off valve in the exhalation circuit.

The adjustable parameters are read as 0 to 5-V voltages through front panel potentiometers. An 8-bit A/D digitizes the voltage and the software adjusts each to the appropriate value for that parameter. All values are displayed on the Liquid Crystal Display (LCD) during operation. A front panel LOCK/UNLOCK switch prohibits the processor from reading the settings so that accidental adjustment is difficult. The processor also monitors the voltage of both batteries and switches in the second when the voltage of the first drops below a preset value. Circuitry on the processor board also implements an 8-bit D/A converter that generates 2.2 to 10.2 V for the adjustable valve.

The power supply board contains two constant-current, voltage-limited chargers for the two lead-acid batteries. A front panel switch selects whether the FFCCU is in battery charge mode or usage mode. Both batteries charge simultaneously. Although there is a switch on the front panel of the mockup to allow direct 120-VAC operation, the 3-amp regulators and some other circuitry required to operate in this mode were not added. They could be easily added at a later time.

The air compressor selected is a Thomas G/07-30W that produces 14.5 LPM at 0 psi and 4.6 LPM at 10 psi. The normal operating pressure should be about 1 psi above atmospheric. This unit is specified to draw 3.1 amps at 12V but bench measurements showed 2.7 to be a more accurate value. This compressor was chosen for its relatively lightweight and small size (5.9" long ,1.93" in diameter, and weighs 1.46 lb). This unit will not ventilate a human without the additional oxygen generators; however, for mockup purposes, it will suffice. A number of slightly larger compressor units are available for the final FFLSS.

The air-flow sensor is a Honeywell Model AWM5104VN (calibrated at the factory with nitrogen). This unit outputs a very linear 1.0 to 5.0V over a flow range of 0 to 20 LPM. It is quite large (6.4" from end to end) but was selected because it has low impedance flow that eases the energy requirements of the compressor and is currently in a ventilator product from Oceanic Medical.

The pressure sensor is a Motorola MPX2010GP that has a range of 0 to 1.45 psi and outputs 25mV full scale. It is located on the processor control board and is connector through internal and external tubing to a point right at the endotracheal tube connection in the patient "Y" circuit so as to measure the actual ventilating pressure without the flow induced drops in the rest of the system. This sensor goes through a 3-op-amp differential instrumentation amplifier to obtain voltages usable to the A/D converter.

The air flow control valve is a Teknocraft Inc. Model 202611 adjustable valve. The exhalation valve, which only implements an ON/OFF function is a model 22R9DGM from Peter Paul Electronics.

Finally, the batteries chosen for the prototype are Panasonic 12 V lead acid cells with 2.2 and 1.3 Ah capacities. Two batteries were chosen so that the feature of the system that allows voltage checking and automatic battery switch over to occur could be implemented and tested. If this feature is implemented in the final FFLSS, it should be accompanied by a radio link warning to the medic that the system is on its reserve battery with approximately 15 to 20 minutes of reserve operation remaining.

3.1.3 Other Hardware Components

COTS components will be used for the pulse oximeter, capnograph, ECG and other equipment as appropriate in the final FFLSS system. The summary of vendors contacted during Phase I is listed as Table 2. A complete description is listed in Appendix D.

Table 2 List of Vendors

VENDOR	ADDRESS	TELEPHONE
Aerospace Optics Inc.	3201 Sandy Lane, Fort Worth, TX 76112	(817) 451-1141
ASF Thomas Compressors & Vacuum Pumps	2100 Norcross Pkwy, #120, , Norcross, VA 30071	(770) 441-3611
Baxter Healthcare Corp I.V. Systems	Division Route 120 & Wilson Rd., Round Lake, IL 60073	(800) 933-0303
BCI International	W238 N1650 Rockwood Dr., Waukesha, WI 53188	(800) 588-2345
BioSTAR Inc.	12321 Middlebrook Rd., Suite 210, Germantown, MD 20874	(301) 916-1007
Dr. Jonathan Newell	2 Coventry Rd., Coventry, NY 12077	(518) 439-6705
ECRI	5200 Butler Pike, Plymouth Meeting, PA 19462	(610) 825-6000
Electronic Prototypes Inc.	8236 Jepson Pl., Alexandria, VA 22309	(703) 799-4305
Infusion Dynamics, Inc.	5209 Militia Hill Road, Plymouth Meeting, PA 19162	(610) 941-0136
ITOCHU Technology, Inc. Electronic Component Div	2701Dow Ave, Tustin, CA 92780	(800) 347-2484
The Knotts Company	350 Snyder Avenue, Berkeley Heights, NJ 07922	(908) 464-4800
Melcor Thermoelectrics	1040 Spruce St , Trenton, NJ 08646	(609) 393-4178
Michigan Instruments Inc.	389 John Downey Dr., New Britain, CT 06050	(800) 530-9939
Moore Medical Corp.	4717 Talon Ct., S.E. , Grand Rapids, MI 49512	(800) 678-8678
N.B. Cochrane	2900 Loch Raven Rd., Baltimore, MD 21218	(410) 467-4884
Naudain Associates Southern, Inc.	8100 Beechcraft Ave., Gaithersburg, MD 20879	(301) 258-5040
Nellcor Puritan Bennett, Inc.	4280 Hacienda Dr., Pleasanton, CA 94588	800 NELLCOR
Newark Electronics	7272 Park Circle Dr., Hanover, MD 21076	(410) 712-6922
NOVAMETRIX Medical Systems Inc	.P.O. Box 690, Wallingford, CT 06492	(203) 265-7701
Novel Technologies Inc.	12321 Middlebrook Rd., Germantown, MD 20874	(301) 515-6411
Oceanic Medical Products	101 S. 5th St. Suite A , Atchison, KS 66002	(913)367-2737
Ohmeda Medical Systems	1315 W. Century Dr., Louisville, CO 80027	(303) 666-7001

Table 2 List of Vendors Continued

VENDOR	ADDRESS	TELEPHONE
Parker Hannifin Corp Pneutronics Division	26 Clinton Dr., Unit 103, Hollis, NH 03049	(800) 525-2857
Paul Foster Martin	2003K Powers Ferry Rd., Marietta GA 30067	(770) 984-0885
Pulmonetic Systems Inc.	1016 E. Cooley Drive, Suite B, Colton, VA 92324	(909) 783-2280
Sensidyne Inc.	16333 Bay Vista Dr., Clearwater. FL 337600	(800) 451-9444
Zero Enclosures	200 N. 500 West, North Salt Lake, UT 84054	(800) 299-7389

3.1.4 Software Design

Substantial portions of the test software have been developed during the specification and mockup process. A copy of the present version is included in Appendix E. The features that have been written and tested are:

1. Timer interrupts for inhalation and exhalation
2. Reading of voltages and conversion to appropriate values for all four front panel controls.
3. D/A voltage output for variable valve
4. Reading of all four front panel control switches
5. Start-up calibration of flow and pressure sensors (zero offsets only)
6. Relay control of compressor and exhalation valve
7. Calculation of timing parameters form I:E and respiratory rate values
8. Writing of parameters and other data (like STOP/RUN mode) to LCD screen
9. Control loop for adjusting the flow valve
10. Routine for converting pressure sensor reading to a usable value
11. Routine for converting flow sensor reading to a usable value
12. Integration of flow volume to hit target tidal volume
13. Routines allowing different items to be displayed on LCD (not required or critical to system function for this prototype)

Item 9 is critical to the correct operation of the ventilator subsystem. It has not yet been determined how tight (fast) the control loop should attempt to control the flow rate. The timer loop that runs throughout both the exhalation and inhalation cycles currently interrupts the processor every 10 msec. This is similar to the response time of the valve. Therefore, changing the valve setting more than once within each interrupt handler would not be optimum.

3.1.5 Experimental Issues

This cooperative agreement developed a concept and specification only. No development or testing of a complete functioning FFLSS systems was performed.

3.1.6 Development Issues

3.1.6.1 Summary List

This section addresses development issues for designing the FFLSS prototype. First is a summary table listing development issues. Several issues are discussed more specifically in the following subsections.

Table 3 Summary of Future Prototype Development Issues

Issue	Remarks
Modes	Section 3.1.6.2
Power	Section 3.1.6.3
Subsystem reliability, power consumption, heat capacity	
Sensor sensitivity and dynamic range	
Shock, vibration, temperature, humidity, EMI, EMC, and cross section	
Chemical, biological contamination/decontamination	
Electrolytic properties and response	
Interface electronics and fiber-optic requirements	
Hardened electronics and microprocessors	
Packaging and containment	
User training and interfaces	

3.1.6.2 Ventilator Modes

The ventilator modes continue to be a discussion topic. These modes must satisfy the largest user community possible without unduly adding to the ventilator size, weight, power requirements, etc. Preliminary findings indicate that an assist control mode is most suitable for battlefield trauma use.

3.1.6.3 Ventilator Power

Powering the ventilator is a key development issue. Many civilian ventilators use compressed air as the driving source. The ventilator valves may then be electrically or mechanically controlled. However, military and civilian personnel agree that battlefield use of compressed air cylinders is unacceptable. Power source alternatives included the standard compressor, a high-speed turbine, mechanical bellows or pump, and an oxygen generator.

3.1.6.4 Oxygen Generator Issues

Scott Aircraft, Lancaster, New York, is the leading manufacturer of chemical oxygen generators. Their AVIOX Duo-Pak (P/N 802502) off-the shelf, 2-canister, 40-minute oxygen generator product is very close to the 60 minutes needed for the FFLSS. Several meetings were held at Scott Aircraft to understand their technology.

The canister (P/N 802111-00) is fabricated from copper and advertises a 5 to 10 year shelf life. It is 2.5 inches in diameter, 8 inches long, and weighs 2.5 lb. It produces 4 to 6 liters per minute of oxygen for 20 minutes at 40 psi. The exothermic reaction produces in excess of 70,000 calories (293,000 Joules) and the canister surface temperature reaches over 450 degrees F. Therefore, over the 20 minute burn time of the reaction, heat is produced at approximately 244 watts. Using thermoelectric devices, e.g. Melcor, Trenton, NJ, with a conservative 5 to 10 percent efficiency, 12 to 24 watts at 12 VDC should be produced. This will help to reduce the battery size needed to power the entire ventilator system for 60 minutes. The excess heat can also be used to warm the IV fluid prior to patient delivery. Heat transfer design should begin with the Scott Duo-Pak design which weighs 5 lb without the two canisters installed.

3.2 Results and Discussion

3.2.1 Mockup Results

The criteria for selecting the major components of the FFLSS mockup are described in the following sections.

3.2.1.1 Compressor

The compressor selected was a Thomas rotary compressor. The selection criteria are as follows:

1. Output suitable for future animal tests and potentially usable for humans with augmentation from the O_2 cylinders. The required total output for humans is 20 to 25 l/min and the compressor selected, the model G/07-30W produces 13.2 l/min at 1 psi back pressure. This was the flow from the product data sheet. However, in the mockup, with actual valves tubing and other resistances, the maximum flow was found to be 180 cc/sec or 10.8 l/min. Another model, the G/07-N produces 18.3 l/min and is actually smaller and lighter than the G/07-30W. However, it draws 51 rather than 37 W.

2. Supply voltage: must be 12 VDC
3. Power: the lower the better, as long as sufficient airflow is produced.
4. Vacuum: compressor must be capable of producing vacuum for suction.
5. Size/weight: Weight is more important but the lighter the better. The G/07-30W and G/07-N weigh 1.46 lb and 1.13 lb respectively.

3.2.1.2 Microprocessor

The MC68HC11 microprocessor was selected because it contains many system components on a single chip. These include an 8-bit A/D converter with 8-channel analog multiplexer, serial interface, as well as others, 5 on-chip timers, 2-K of EEPROM, and 256 bytes of RAM. For the prototype, the processor was used in the single-chip mode meaning that no external memory was used.

This processor may suffice for the final unit. However, if data storage features as well as integration of the communication system and additional sensors are implemented, it will be necessary to migrate to the Motorola XC68HC12A4. The X in its model number indicates that this is still an experimental chip that should be in commercial form by the end of 1998.

3.2.1.3 Proportional Valve and Exhalation Valve

Both of these valves shared common problems. The biggest problem is that most air flow valves are designed and even optimized to work at pressures of 35 to 100 psi. The highest internal pressure in the FFCCU will be about 4 psi and the main operating pressure is about 1 psi. This low pressure was selected for these reasons. The first is that less than 1 psi above atmospheric pressure is required to inflate the lungs. The second reason is that the energy consumed is proportional to the airflow rate times the pressure. Therefore, a low-pressure system will be more energy efficient.

The problems encountered in locating a valve for this system were that the valves were large and heavy due to their ability to handle high pressure. Secondly, the range of control for the proportional control valve was over a narrow range of control voltages. Even after a mechanical offset adjustment was made on the valve, the range of voltages that affected the flow rate was 7.8 to 8.8 V.

3.2.1.4 Flow Sensor

The flow sensor was selected based largely on recommendation from Oceanic Medical Products, Inc., a small manufacturer of ventilators that has been collaborating with JHU/APL on some portions of this project. The unit functions as predicted but is somewhat larger than is desirable (about 6 inches from end to end). Additionally, its ruggedness is suspect in that the torque moment placed on the tubing connectors by the airflow tubes appears to have the potential to distort the flow sensor housing. No mechanical tie-down points are near these connections, only near the center of the sensor. Therefore, if this sensor is selected for the final FFLSS, care will have to be taken in the design and fabrication stages to minimize forces on the sensor. Another observation made during testing of the prototype is that the airflow from the rotary compressor has a substantial pulsatile component. This contributed 0.5 V peak to peak AC ripple on the output voltage from the flow sensor. If the sampling of the A/D converter happens to coincide with the peak or valley, the error could yield a 10percent error in flow measurement. A simple single pole RC filter was added to the front of the A/D multiplexer on this channel: this addition removed most of the ripple.

3.2.1.5 Pressure Sensor:

The Motorola MPX2010GP pressure sensor was selected. This unit, when fed through a 3-operational amplifier instrumentation amplifier, yielded results that agreed within 1 mm Hg with an optical pressure calibration standard. This sensor will be sufficient for the final FFLSS.

3.2.1.6 Batteries

The batteries selected were lead acid because these are rechargeable and also because they hold their charge for a long period of time. The exact sizes of the batteries in the final FFLSS will depend on the compressor selected. The compressor will use 80 to 90 percent of the total system power. Two batteries were used so that the processor could switch over to a second battery when the first one is getting low. At this point, a communication link would signal a medic that the FFCCU is on the back-up battery. Still later, while monitoring battery voltages, the unit could send further warnings that the back-up power was also becoming dangerously depleted.

3.2.1.7 Power Supply/Transformer:

The transformer was selected for quick availability and is not likely to be the one used in the final FFLSS. A small switching supply capable of about 5 amps at 12 VDC will most likely be selected.

3.2.1.8 Mockup Summary

The ventilator subsystem mockup weighs 13.4 lb (without the case). The batteries described in Section 3.2.1.6 weigh 2.6 pounds. Each of the three oxygen generators (discussed in Section 3.1.6.4) weighs 2.5 lb for a combined total weight of 7.5 pounds. Currently, the system total weight is 23.5 lb, with only 1.5 pounds available for the case, and all off the shelf physiologic sensors.

The mockup filled the need to assemble the pieces necessary for the ventilator subsystem, but was not built to address the need for minimum weight. Thirty, convenient to obtain brass fittings were used to simplify the plumbing in the mockup which added significant weight. Also, the two (off the shelf) low pressure valves weighed a total of three pounds. There are significant weight savings available using this mockup as the starting point.

The following photographs show details of the current FFLSS ventilator subsystem mockup

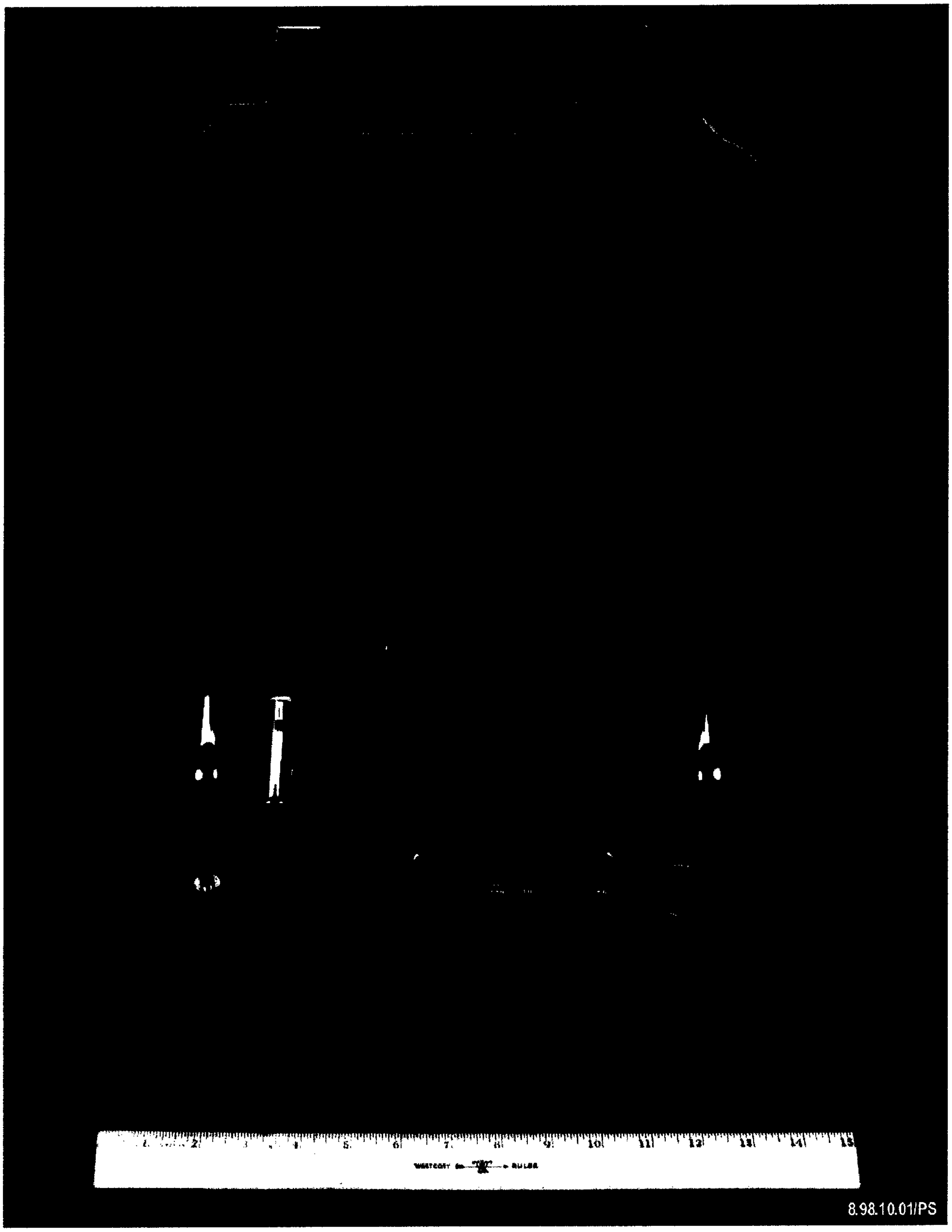


Figure 3.2.1-1 Ventilator Mockup Overview

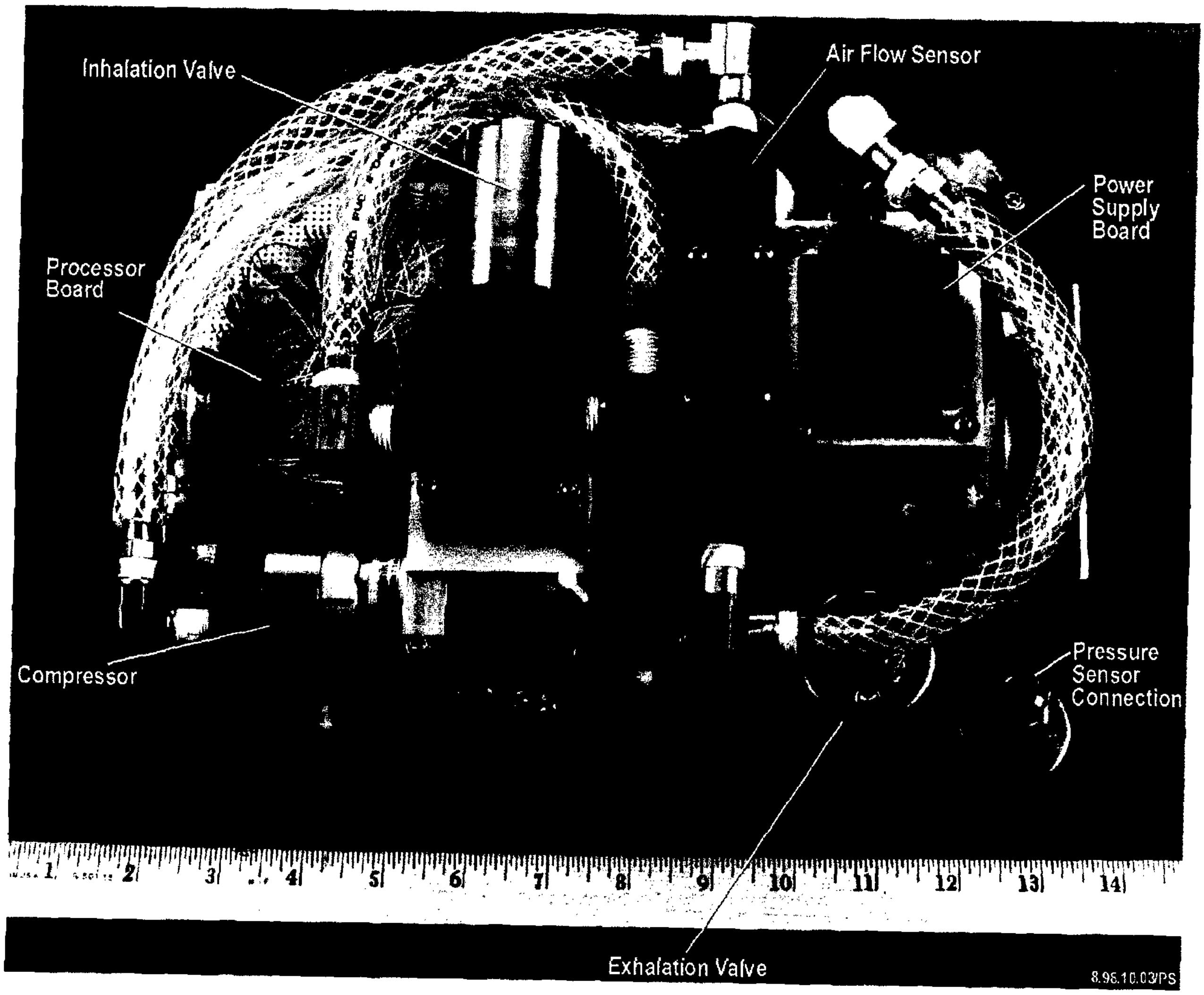


Figure 3.2.1-2 Ventilator Components

Figure 3.2.1-3 Ventilator Switches

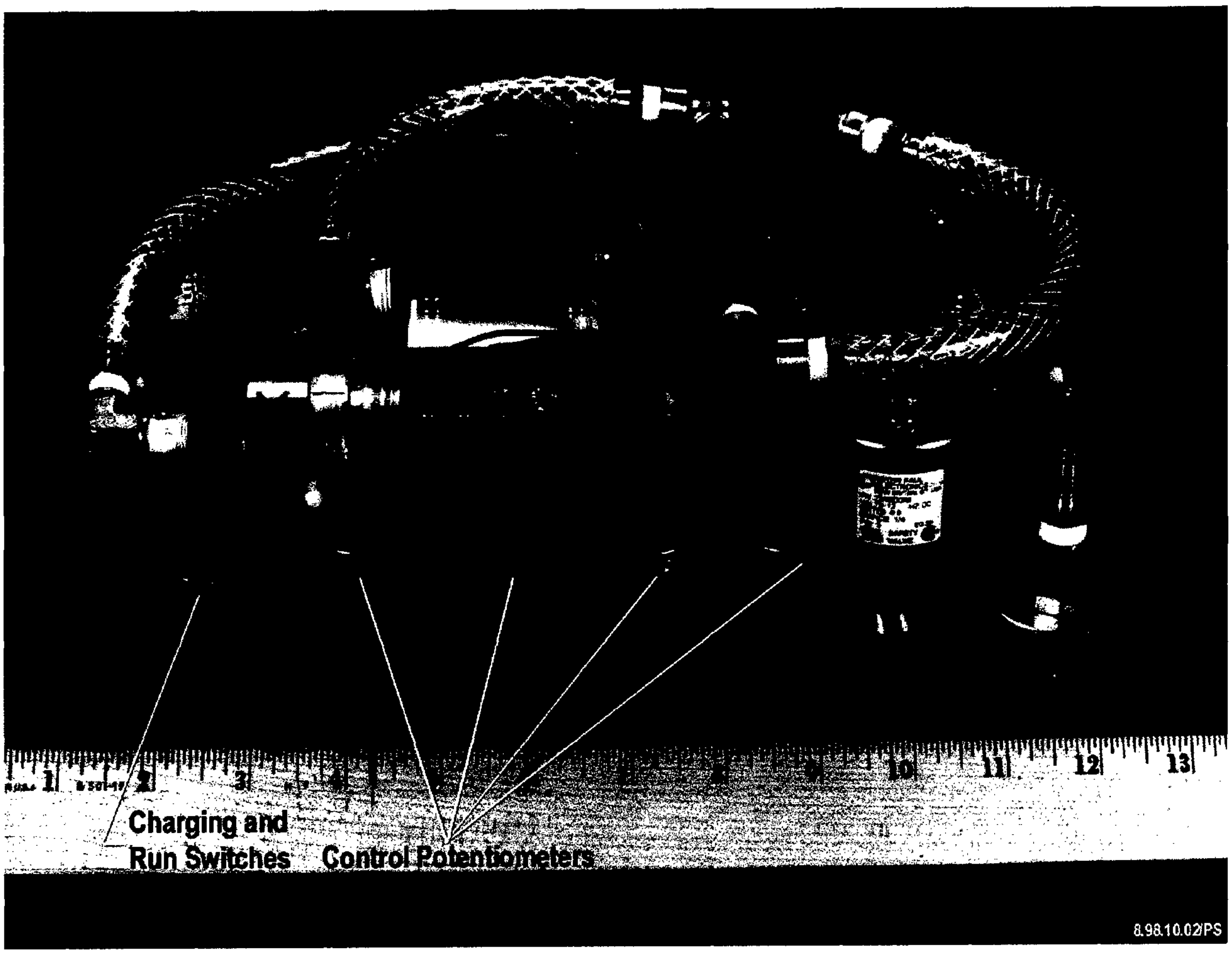
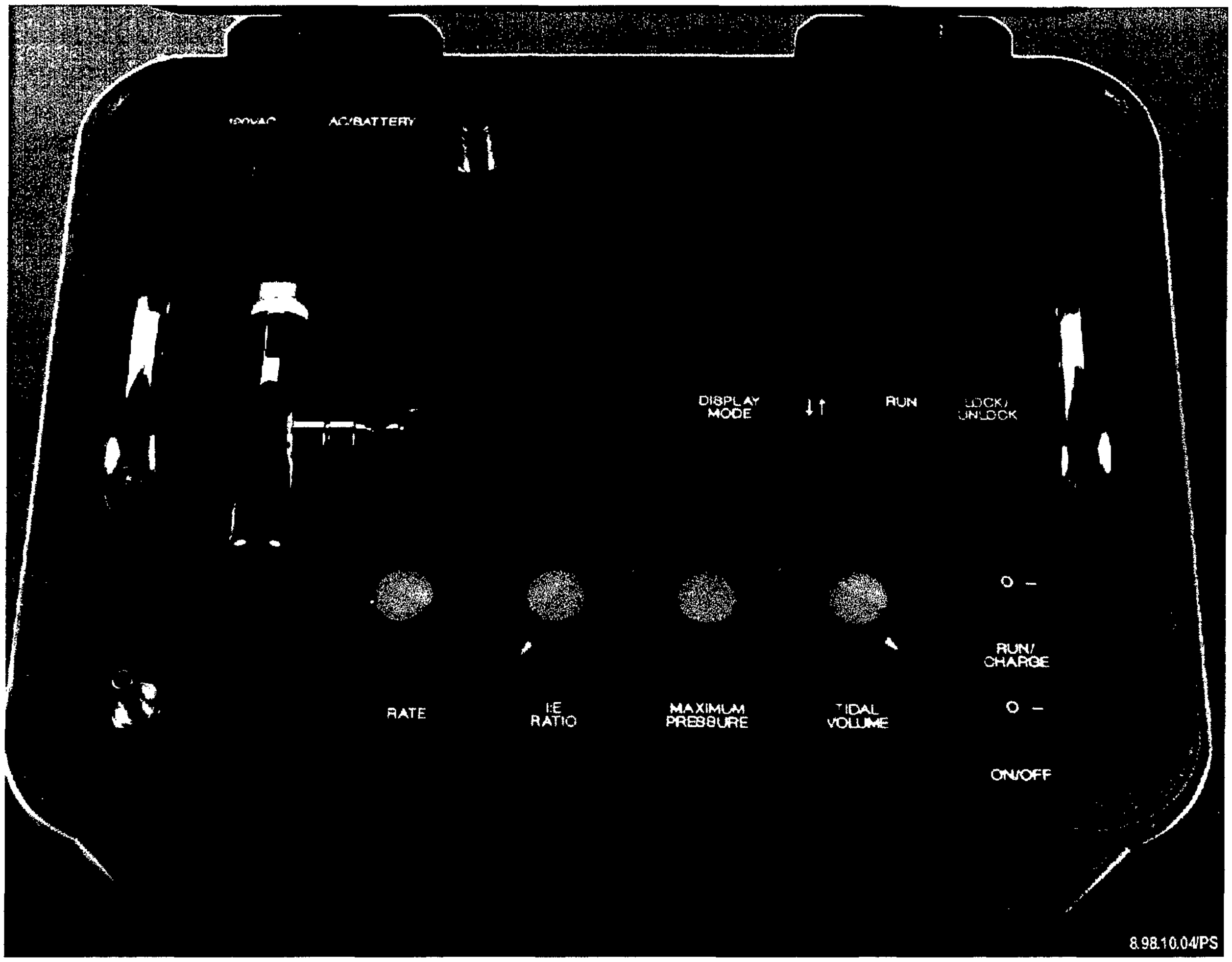


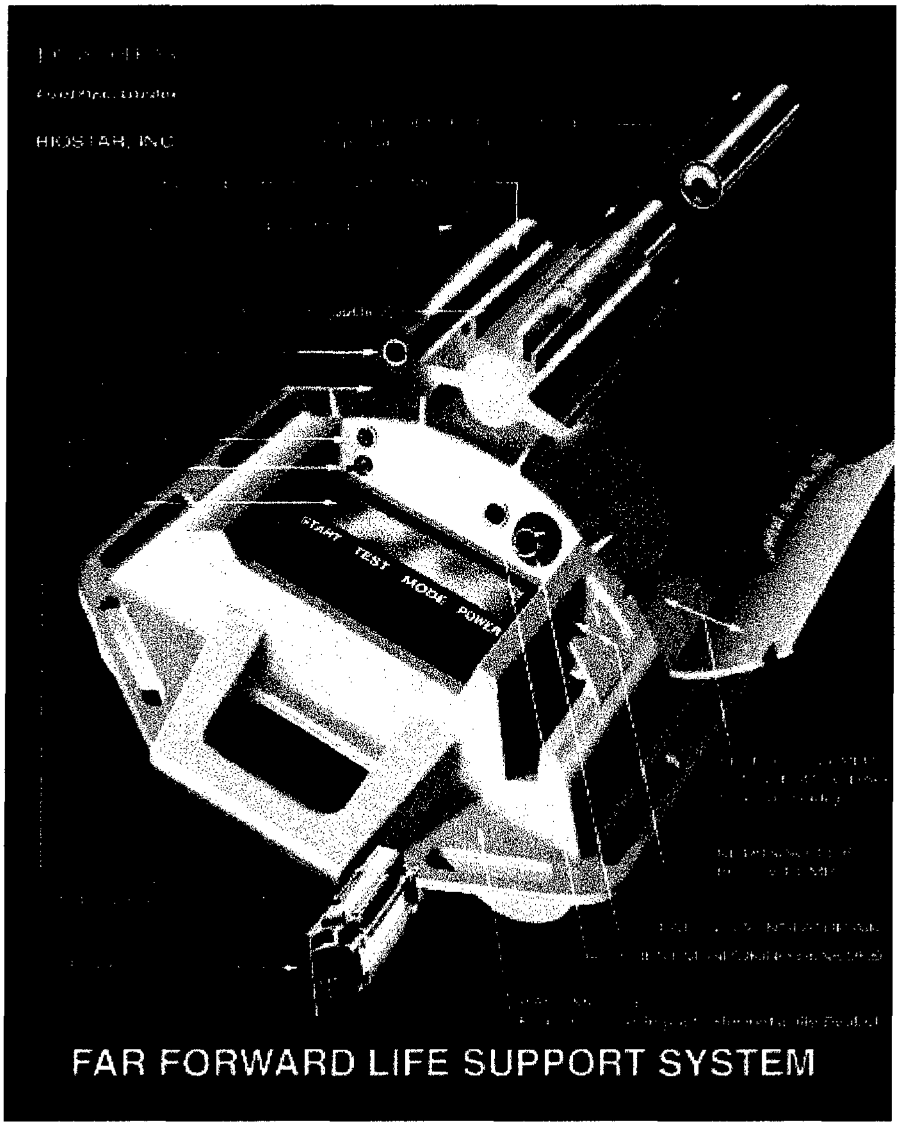
Figure 3.2.1-4 Ventilator Mockup Control Panel



3.2.2 System Concept Results

The Far Forward Life Support System (FFLSS) depicted in Figure 3.2.2-1. represents an ideal target design that meets all of the specifications and requirements described in Section 3.4. This lightweight package is approximately 18 inches wide and 22 inches long and about 6 inches deep. What is not shown in the figure is a curved back support structure that will allow the FFLSS to lie alongside the patient and attach to either an extremity or the chest in order to be co-located as close to the patient as possible. Outlets for the tubing, power, and oxygen, as well as the ventilatory connections and patient monitoring sensors are easily accessible to the patient and to the user. Only four buttons are required to operate the device: the large alpha-numeric display, located on the top of the device, can be viewed easily by the operator. The FFLSS is designed to be constructed from a lightweight, highly durable plastic material and can be produced in any color desired. Recessed panels for IV fluids and the incorporation of an IV pump are conveniently located for operator use and accessibility. Strap attachment ports and slots are provided on each side, permitting the device to be attached to a wall, a transport vehicle, a stretcher or to an ambulance interior. The detachable oxygen canister pack can be refitted with oxygen generating generators in a plug in-plug out mode during use or the entire pack can be replaced. Alternatively, if the FFLSS is operated by supplemental oxygen and gas, this oxygen generator pack can be removed and the device can operate with a smaller footprint. Within the power oxygen heater module is a site to attach the IV tubing. This design takes advantage of the heat produced by the candles and enables IV fluid to be warmed as it is infused into the patient. The entire unit is designed to be hermetically sealed and to operate while wet, or even partially submerged. While the ergonomics of the system are not entirely resolved, the design shown in Figure 3.2.2-1 is the most likely representation of the final unit (based on the experience obtained in this Phase I effort). Slight modifications in positioning the operating dials, the alpha-numeric display, the patient ventilator and monitoring outputs, and the actual placement of the oxygen generating generators on the device may be appropriate in order to more seamlessly integrate the subsystems and/or for manufacturing considerations.

Figure 3.2.2-1 FFLSS System Concept



3.3 Problems Encountered

The primary technical issue encountered was the lack of readily available, lightweight, electrically controllable, low pressure valves. Operating at less than 5 psi instead of the usual 40 to 60 psi proved to be a challenge. A Phase II prototype may require custom fabricated valves or more extensive vendor searching.

3.4 Recommendations

3.4.1 Final Draft Specification

The following tables detail the components and subsystems for the final FFLSS specification.

Table 4 Final Draft Specification FFLSS Components

VENTILATOR SUBSYSTEM	COMMENT
(3) Oxygen Generators (mounted for use)	
Air Compressor	
2 valves and control interface	
Air Mask	
Air Input Jack	
Suction port	TBD
NBC filter (on outside air)	
Fluid Resuscitation	
Infusion Pump	Self-contained
IV fluids	On-board
IV Tubing	On-board
IV fluid warming	Use excess heat from O_2 generators
Physiologic Sensor Arrays	
Pulse Oximetry Sensor	OEM Board
Capnography Sensor	OEM Board
ECG	OEM Board
BP Cuff and control	
Electronic Control	
System control board	Motorola processor TBD
Data Port	Serial
LCD display	40 x 2 min
Push Switches	Daylight readable, LCD TBD
Communications	TBD
Alarms	TBD
Other	
Light Source	
Power	
Power Input Jack	TBD
Battery - minor functions	1.2 Ah, 12 VDC
Battery - compressor, light, etc.	2.3 Ah, 12 VDC
Heat	
Thermo-electric devices	12 VDC, 20 watts min
Candle / IV / Thermoelectric heat sink/exchange unit	
Structure / Mounting	
Durable Packaging (shock, environment, EMI, etc.)	
Mounting surface	
Handle / Strapping Points	
Cleanable (biological decontamination) surface	

Table 5 Final Draft Specification FFLSS Requirements

Item	Comments	Item	Comments
Overall		**Special Considerations**	
Size	1 ft^3	*Non-Flammable*	
Weight	<25 lb	CW Corrosion Resistant	
Production	$15,000/unit	Low Outgas	
Cost		Low Radar Cross Section	0 dB rel m^2
Operation Time	1 hr	Low Emissivity/Radiation	10^{-1} watts
Telemetry	On demand	**Platform**	
Operating Properties		Land Motor Vehicle	12 VDC
Temperature	-20°C to 70°C	Fixed Wing Aircraft	12 VDC
Vibration	0 to 20 g, 0 to 500 Hz	Rotary Aircraft	12 VDC
Pressure	10^{-1} to 2 ATM	Field Hospital	12 VDC; 120 VAC / 60 Hz
Isolation	Ground Plane & Patient	**Subsystem Requirements**	
Packaging Requirements		Ventilator	
Size	1 cm ft^3, 19" Rack Compatible	Adjustable	Rate (5-20), Tidal Vol. (400-1000 cc)
Construction	Double Insulated, Water Washdown, Accessible Battery Compartment, Optional Removable Lid	Modes	Assist/Control, Others TBD
Paint	Low Optical Reflectivity, Non-conducting	Interface	RS232, Baud Rate TBD
Functionality	360° Roll, Pitch, Yaw Functionality	Oximeter	
Interfaces		Accuracy	+/- 2%, Range 0% to 100%
LSTAT		Sample Rate	120 Samples/Second
Personal Data Monitor (PDM)		Sensor	Transcutaneous Optical
Communications	TBD	Interface	RS232
Mounts	19" Rack, Backpack, Seat Harness	ECG	
Data Acquisition and Protocol		Heart Rate	0-250 BPM
Features		Flags	Asystole, Lead-Off, Excessive Heart Rate
Date-Time		Waveform	12 Bit ECG @ 120 Samples/Second
Patient ID		Interface	RS232 @ 38.4 K Baud
Flags, Alarms		Capnograph	
Input Selections		Range	0-100 mm Hg
Protocol	RS232 *Compatible*, 9600 Baud, 8 Bits, Error Detection & Correction	Accuracy	+/- 2 mm Hg (0-40 mm Hg) +/- 5% (41-70 mm Hg)
Compatibility / Certification		Resolution	1 mm Hg
LSTAT		Compensations	NO2, O2
EMI (UH-1, UH-60)		**Infusion Pump**	Specifications in Infusion Dynamics Brochure
FAA		**Suction**	TBD
FDA			
C4I			

4 Conclusions

4.1 Importance/Implication of Completed Research

Aggressive far forward casualty care should reduce the pre-hospital mortality rates experienced by American Forces on the battlefield and shrink the footprint of battlefield medical logistics. Initial improvements must be directed at hemorrhage control and hemostasis. However, ventilatory support following acute respiratory failure secondary to inhalational injury, penetrating thoracic injury, and respiratory paralysis following chemical weapon exposure is mandatory for successful rescue of battle casualties. While the Life Support Trauma and Transport platform fills this need in the far forward surgical and tactical transport domain, LSTAT clearly has no role for first responders in the battlefield environment. Filling this void is the rugged and lightweight FFLSS, an affordable life support system specifically designed for first responders. The FFLSS was designed to operate within the logistical limitations of the forward area and to provide critical life-saving support during the crucial minutes after an injury and during evacuation. This FFLSS can substantially reduce the mortality rate associated with trauma, shock and respiratory compromise due to chemical and biological agents.

This Far Forward Life Support System addresses consensus requirements for first responder in the battlefield environment. The significant FFLSS characteristics are:

1. Adapts to multiple transport and logistical scenarios including Medic transport, armored transport, aviation systems and operates within the constraints imposed for far-forward operations.
2. Is lightweight-self-contained, and features an autonomous architecture that provides a simple, low-cost, first responder apparatus for initial patient data acquisition. As the system advances, the data gathered by the sensor system will allow digitally controlled optimized care to the patient.
3. Continuously records selected patient data and then provides that data to other medical care systems after the patient is transported to a field hospital or other similar location.
4. Remains self-contained and operational for a minimum of one hour without additional power.
5. Provides a low-power, lightweight ventilator system. In the future, the system will provide an integrated controller capable of digitally controlling the pump and ventilator to optimize patient care.
6. Provides an integrated pulse oximeter for measuring oxygen saturation in the blood stream. This data will provide feedback on the effectiveness of ventilation efforts or the patient's own respiration.
7. Integrates a capnograph for measuring the effectiveness of breathing and of endotrachiotube (ETT) placement and avoidance of hyperventilation. The data provides feedback on the effectiveness of ventilation efforts or the patient's own respiration.

8. Integrates an ECG monitoring system for measuring cardiac function.
9. Integrates an infusion pump for the delivery of fluids into the patient to manage the effects of shock.
10. Provides suction capability.

4.2 Significance of Research

The FFLSS fulfills a need for military medical care that would otherwise remain a deficiency in our capabilities. The LSTAT™ is currently being developed to provide advanced medical care to our soldiers closer to the site of injury; however, its size and weight make it impractical to be taken to the soldier at the site of injury. The FFLSS brings many of the functions of advanced life support, and can easily be deployed to our casualties *at the location of the injury.* This provides a vast improvement in care over the "buddy care" system of bandages and IVs currently available.

Currently, there is no transportable system that can provide acute ventilatory support for combat injuries or chemical or biological weapon paralysis of the ventilatory system that can be delivered in a package and operated by a medic in a time frame that is consistent with the survival of the injured soldier. The FFLSS will provide that capability in a very small, controlled, easily operated package and will, most assuredly, contribute to life support and life saving capabilities for the U.S. militaries. Conservatively, a FFLSS capability could reduce total combat mortality by 5 to 10 percent, or even more if chemical weapons are involved in a future encounter by U.S. military forces.

4.3 Recommendations

Phase II efforts should design and fabricate a prototype FFLSS as a proof-of-concept demonstration of a portable, lightweight ventilator with no compromising emanations.

5 Bibliography

5.1 Contract Publications, Presentations and Meeting Abstracts

This work has not been submitted for publication or presented at any meeting.

5.2 List of Personnel

A listing of JHU/APL and BioSTAR personnel who performed work for the FFLSS project is presented in Table 6.

Table 6 List of Personnel

JHU/JHU/APL PERSONNEL	BIOSTAR PERSONNEL
Bowman, James D.	Draghnic, Nicole (contractor)
Cutchis, Protagoras, N. Dr.	Martin, Paul F. (contractor)
Denney, Theresa L.	Pranger, L. Alex
DuBois, Sharon, K.	Swift, Pat
Ko, Harvey W. Dr.	Weismann, William P. Dr.
McLoughlin, Jacqueline M.	
Medley, William C.	
Sanders, Lisa G.	
Schulyer, Robert C.	
Smith, Dexter G. Dr.	
Starsoneck, Richard L.	
Trossbach, Marianne C.	
Walker, Robin A.	
White, Ruth R.	
Wiley, Karen	
Will, Jeffrey T.	

5.3 List of Graduate Degrees Resulting from Research

None

6 References

Medical Physiology 13th edition Vernon B. Mountcastle, ed., C. V. Mosby Company, St. Louis, Mo,1974.

Textbook of Medical Physiology 5th edition, Arthur C. Guyton, ed., W. B. Saunders Company, Philadelphia, PA, 1976.

7 Appendices

Appendix A. Army Technical Architecture Compliance

For the proposed effort, compliance with the U.S. Army Technical Architecture is not applicable. However, in the future, it might be desirable to transport data derived from the FFLSS (perhaps for a casualty tracking system or other "telemedicine" needs). Accordingly, the FFLSS will be designed so that migration to the Army Technical Architecture will not require substantial redesign.

The Army Technical Architecture compliance matrix for the FFLSS follows.

Table A-1 FFLSS Army Technical Architecture (ATA) Compliance Matrix

ATA REFERENCE	APP	N/A	ATA REFERENCE	APP	N/A
Section 2: Information Processing and Standards			3.2.1.3: File Transfer - FTP	2	
2.2: COE Concept; GCCS COE APIs	2		3.2.1.3: Remote Terminal - TELNET		1
2.2.1: Max use of GCCS COE Support Applications	2		3.2.1.3: Electronic Mail - DMS Compliant x.400	2	
2.2.2.1.1.1: Programming Language	2		3.2.1.3: Directory Services - X.500		1
2.2.2.1.1.2: Language Bindings & Object Linking	2		3.2.1.3: Booting without disks - BOOTP		1
2.2.2.1.2: User Interface Services	2		3.2.1.3: Dynamic Configuration - DHCP	2	1
2.2.2.1.3: Data Management Services for use with Relation Database Management System		1	3.2.1.3: Hypertext Transfer - HTTP		1
2.2.2.1.4.1: Document Interchange	2		3.2.1.3: Translating Names to Addresses - DNS	2	
2.2.2.1.4.2: Graphics Data Interchange	2		3.2.1.3: Connectionless Application Layer MIL-STD-2045-47001 for VMF Messages	2	
2.2.2.1.4.3: Imagery Data Interchange	2		3.2.1.4: Network Management Services SNMP Set of Management Protocols		1
2.2.2.1.4.4: Product Data Interchange	2		3.2.1.5: Video Teleconferencing Standards	2	
2.2.2.1.4.5: Electronic Data Interchange	2		3.2.1.6: Global Position System (GPS) Standards	2	
2.2.2.1.5: Graphic Services	2		3.2.2: Router Standards STD-4		1
2.2.2.1.7: Operating System Services - POSIX APIs	2		3.2.3.1: Serial Lines	2	
2.2.2.2.1: Character Set Coding Standards	2		3.2.3.3.: Fiber Distributed Data Interface (FDDI)		1
2.2.2.2.4: Distributed Computing Services		1	3.2.3.4: Asynchronous Transfer Mode (ATM) ATM Adaptation Layer Protocols (AAL1, AAL5)	2	
Section 3: Information Transport Standards			3.2.3.5: X.25 Packet Switched Networks	2	
3.2.1: Host Standards STD-3	2		3.2.3.6: Integrated Services Digital Network (ISDN)		1
3.2.1.1. Internetwork Layer Standards STD-5 defines IP protocol	2		3.2.3.7: MIL-STD-188-220A	2	
3.2.1.2: Transport Layer Standards STD-6 for UDP; STD-7 for TCP	2				

Table A-1 FFLSS Army Technical Architecture (ATA) Compliance Matrix (continued)

ATA REFERENCE	APP	N/A	ATA REFERENCE	APP	N/A
Section 4: Information Modeling and Data Exchange Standards			6.3.2.2: World Wide Web - Secure HTTP		1
4.2.1: Process Model (IDEF 0)			6.4: Information Modeling and Data Exchange Security Standards		1
4.2.2: Data Model - DOD Enterprise Data Model (EDM)/C2 Core Data Model; IDEF 1X for Data Model Extensions	2		6.5: Human-Computer Interface Security Standards	2	
4.2.3: Data Definitions - DDDS as Primary Source	2		Appendix D: Sustaining Base/Office Automation Domain: Exceptions and Extensions		
4.2.4.2: Variable Message Format (VMF) Messages	2		D.2.1.2: User Interface Service Extensions - WIN32 APIs	2	
4.2.4.3: US Message Text Format (USMTF Messages)	2		D.2.1.2: Data Management Services Extensions - Open Data Base Connectivity (ODBC 2.0)		
4.2.4.4: Tactical Data Information Link (TADIL-J Series Messages)		1	D.2.1.2: Operating System Services WIN31 APIs	2	
4.2.4.5: Remote Procedure Calls		1	D.5.1.2: HCI Style Guide Extensions: WindowsTM Interface	2	
Section 5: Human Computer Interfaces			Appendix E: C3I Domain: Exceptions and Extensions		
5.2.1.1: Graphic User Interfaces Precludes Hybrid GUIs: Commercial GUIs Given Preference Over Custom GUIs			E.5: Human Computer Interface: Supplement to DoD HCI Style Guide	2	
5.2.1.2: Character-based Interfaces - per DoD HCI Style Guide Design Criteria	2		Appendix F: Weapons System Domain: Exceptions and Extensions		
5.2.1.3: Common Warfighting Symbology (M-S-2525)		1	F.2.1.1: Graphic Service Exception	2	
5.2.2: Style Guide Hierarchy Guidance	2		Appendix G: Modeling and Simulation Domain: Exceptions and Extensions		
Section 6: Information Security			G.3: Information Transport Standards-DIS Communication Services and Profiles		1
6.2.1.1: Application Software Security-FORTEZZA Card Interface Standards; Security Evaluation Criteria Standards			G.4: Information Modeling and Data Exchange Standards - DIS Application Protocols; DIS Exercise Management and Feedback		
6.2.1.2: Application Platform Security - Labeling Standard; Security Alarm Reporting; Security Evaluation Criteria Standard		1			
END					

Appendix B Journal Articles

N/A

Appendix C Study Questionnaires

N/A

Appendix D Vendors

Table D-1 List of Vendors

VENTILATOR ITEM	VENDOR	TELEPHONE	COMPONENT	MFG	MODEL /PART NUMBER	WGT (LBS)	QTY
CAPNOGRAPH/ OXIMETER	BCI International W238 N1650 Rockwood Dr. Waukesha, WI 53188	(800) 588-2345	Isolated SpO2/ECG PWB and Software	BCI	P/N 57548B1 P/N 57554A1		1
CAPNOGRAPH/ OXIMETER	BCI International W238 N1650 Rockwood Dr. Waukesha, WI 53188	(800) 588-2345	Non-Isolated SpO2/ECG	BCI	P/N 70752B1		1
CAPNOGRAPH/ OXIMETER	BCI International W238 N1650 Rockwood Dr. Waukesha, WI 53188	(800) 588-2345	Isolated SpO2/ECG	BCI	P/N 20502B1		1
CAPNOGRAPH/ OXIMETER	BCI International W238 N1650 Rockwood Dr. Waukesha, WI 53188	(800) 588-2345	Model 8200 Capnocheck	BCI			2
CAPNOGRAPH/ OXIMETER	BCI International W238 N1650 Rockwood Dr. Waukesha, WI 53188	(800) 588-2345	Model 9100 Capnocheck Plus	BCI			2
CAPNOGRAPH/ OXIMETER	Nellcor Puritan Bennett, Inc. 4280 Hacienda Dr Pleasanton, CA 94588	800 NELLCOR		NELLCOR			
CAPNOGRAPH/ OXIMETER	NOVAMETRIX Medical Systems Inc. P.O. Box 690 Wallingford, CT 06492	(203) 265-7701		Novametrix		8.00	2
CAPNOGRAPH/ OXIMETER	NOVAMETRIX Medical Systems Inc. P.O. Box 690 Wallingford, CT 06492	(203) 265-7701	EtCo2 & Spo2 Module Assembly	Novametrix	P/N 5951-01		1
CAPNOGRAPH/ OXIMETER	NOVAMETRIX Medical Systems Inc. P.O. Box 690 Wallingford, CT 06492	(203) 265-7701	Power Supply Board Assembly	Novametrix	P/N 2472-01		1
CAPNOGRAPH/ OXIMETER	NOVAMETRIX Medical Systems Inc. P.O. Box 690 Wallingford, CT 06492	(203) 265-7701	Etco2 Input Board Assembly	Novametrix	P/N 2488-01		1

Table D-1 List of Vendors Continued

VENTILATOR ITEM	VENDOR	TELEPHONE	COMPONENT	MFG	MODEL /PART NUMBER	WGT (LBS)	QTY
CAPNOGRAPH/ OXIMETER	NOVAMETRIX Medical Systems Inc. P.O. Box 690 Wallingford, CT 06492	(203) 265-7701	Power Entry Module	Novametrix	P/N 5743-10		1
CAPNOGRAPH/ OXIMETER	NOVAMETRIX Medical Systems Inc. P.O. Box 690 Wallingford, CT 06492	(203) 265-7701	Model 7100 Membrane Keypanel	Novametrix	P/N 5763-27		1
CAPNOGRAPH/ OXIMETER	NOVAMETRIX Medical Systems Inc. P.O. Box 690 Wallingford, CT 06492	(203) 265-7701	Display Board Assembly	Novametrix	P/N 5720-01		1
CAPNOGRAPH/ OXIMETER	NOVAMETRIX Medical Systems Inc. P.O. Box 690 Wallingford, CT 06492	(203) 265-7701	Model 7100 Service Manual	Novametrix	P/N 5758-90		1
CAPNOGRAPH/ OXIMETER	Ohmeda Medical Systems 1315 W. Century Dr. Louisville, CO 80027	(303) 666-7001		Ohmeda	MINX	0.281	
CASE	CASEMAN 1777 Ebers St. San Diego, CA 92107	800-CASEMAN	Carrying Case	Pelican	1400	4.00	1
CASE	Michigan Instruments Inc. 4717 Talon Ct., S.E. Grand Rapids, MI 49512	(800) 530-9939	Carrying Case				1
CASE	Naudain Associates Southern, Inc. 8100 Beechcraft Ave Gaithersburg, MD 20879	(301) 258-5040	Carrying Case	Zero Enclosures 200 N. 500 West P.O. Box 540310 North Salt Lake, UT 84054 800-299-7389	103P-2-A-J-5		1
ELECTRONICS	Aerospace Optics Inc. 3201 Sandy Lane Fort Worth, TX 76112	(817) 451-1141	Electro-Optical Display		Vivisun 5000		
ELECTRONICS	ITOCHU Technology, Inc. Electronic Component Division 2701Dow Ave Tustin, CA 92780	(800) 347-2484	Development System	ITOCHU	DKP808-WB-S		1

Table D-1 List of Vendors Continued

VENTILATOR ITEM	VENDOR	TELEPHONE	COMPONENT	MFG	MODEL /PART NUMBER	WGT (LBS)	QTY
ELECTRONICS	ITOCHU Technology, Inc. Electronic Component Division 2701Dow Ave Tustin, CA 92780	(800) 347-2484	Graphic LCD Module (with switch)	ITOCHU	D880HxCRG-WB		1
ELECTRONICS	ITOCHU Technology, Inc. Electronic Component Division 2701Dow Ave Tustin, CA 92780	(800) 347-2484	Graphic LCD Module (no switch)	ITOCHU	D880HCRG-WB		1
ELECTRONICS	ITOCHU Technology, Inc. Electronic Component Division 2701Dow Ave Tustin, CA 92780	(800) 347-2484	Graphic LCD Module Low Profile Socket	ITOCHU	DS800		1
ELECTRONICS	ITOCHU Technology, Inc. Electronic Component Division 2701Dow Ave Tustin, CA 92780	(800) 347-2484	Graphic LCD Module Adapter Board	ITOCHU	DB850		100
ELECTRONICS	ITOCHU Technology, Inc. Electronic Component Division 2701Dow Ave Tustin, CA 92780	(800) 347-2484	Graphic LCD Module Panel Mount Housing-Flush	ITOCHU	DPM1		4
ELECTRONICS	ITOCHU Technology, Inc. Electronic Component Division 2701Dow Ave Tustin, CA 92780	(800) 347-2484	Graphic LCD Module Panel Mount Housing-Protruding	ITOCHU	DPM2		4
ELECTRONICS	ITOCHU Technology, Inc. Electronic Component Division 2701Dow Ave Tustin, CA 92780	(800) 347-2484	Graphic LCD Module Logic Board	ITOCHU	DB857		1
ELECTRONICS	ITOCHU Technology, Inc. Electronic Component Division 2701Dow Ave Tustin, CA 92780	(800) 347-2484	Graphic LCD Module Rubberfoot	ITOCHU	88108		4

Table D-1 List of Vendors Continued

VENTILATOR ITEM	VENDOR	TELEPHONE	COMPONENT	MFG	MODEL /PART NUMBER	WGT (LBS)	QTY
ELECTRONICS	ITOCHU Technology, Inc. Electronic Component Division 2701Dow Ave Tustin, CA 92780	(800) 347-2484	Graphic LCD Module Lens for Rubberfoot	ITOCHU	88107		4
ELECTRONICS	ITOCHU Technology, Inc. Electronic Component Division 2701Dow Ave Tustin, CA 92780	(800) 347-2484	Cable Assembly 50 Pin(36"-50")	ITOCHU	DCB801		1
ELECTRONICS	ITOCHU Technology, Inc. Electronic Component Division 2701Dow Ave Tustin, CA 92780	(800) 347-2484	Cable Assembly 14 Pin(1"-2")	ITOCHU	DCB81 DCB82		1
ELECTRONICS	ITOCHU Technology, Inc. Electronic Component Division 2701Dow Ave Tustin, CA 92780	(800) 347-2484	Cable Assembly 14 Pin(12"-24")	ITOCHU	DCB812 DCB824		1
ELECTRONICS	ITOCHU Technology, Inc. Electronic Component Division 2701Dow Ave Tustin, CA 92780	(800) 347-2484	Cable Assembly 14 Pin(36")	ITOCHU	DCB836		1
ELECTRONICS	ITOCHU Technology, Inc. Electronic Component Division 2701Dow Ave Tustin, CA 92780	(800) 347-2484	Cable with Connector (RJ11 to DB25)	ITOCHU	Serial Cable		1
ELECTRONICS	Newark Electronics 7272 Park Circle Dr Hanover, MD 21076	(410) 712-6922	LCD Display	OPTREX	DMC-24227		1
ELECTRONICS	JHU/APL		Processor Board	JHU/JHU/APL		0.75	
ELECTRONICS	Newark Electronics 7272 Park Circle Dr Hanover, MD 21076	(410) 712-6922	Microprocessor	Motorola	MC68HC811E2FN	0.00	1

Table D-1 List of Vendors Continued

VENTILATOR ITEM	VENDOR	TELEPHONE	COMPONENT	MFG	MODEL /PART NUMBER	WGT (LBS)	QTY
ELECTRONICS	Newark Electronics 7272 Park Circle Dr Hanover, MD 21076	(410) 712-6922	Aluminum Front Panel	Custom		1.00	1
ELECTRONICS	Newark Electronics 7272 Park Circle Dr Hanover, MD 21076	(410) 712-9622	Pressure Transducer	Motorola	MPX2010GP		1
ELECTRONICS	Newark Electronics 7272 Park Circle Dr Hanover, MD 21076	(410) 712-6922	Air Flow Sensor	Honeywell	AWM5104VN	0.38	1
ELECTRONICS	JHU/APL		Miscellaneous Elec				1
ELECTRONICS	JHU/APL		Miscellaneous Mech				1
GENERATOR	Melcor Thermoelectrics 1040 Spruce St Trenton, NJ 08646	(609) 393-4178	Extruded Fin Heat Sinks	Melcor	EXT202		8
GENERATOR	Scott Aviation 225 Erie Street Lancaster, NY 14086	(716) 683-5100	Dummy Generator Training Aid	Scott	Aviox Portable Duo-Pak with 2 Generator	P/N 80250 2-15	1
	Scott Aviation 225 Erie Street Lancaster, NY 14086	(716) 683-5100	Chemical Oxygen Generator	Scott	P/N 802111-00		10
INDUSTRIAL DESIGN	Dr. Jonathan Newell 2 Coventry Rd. Coventry, NY 12077	(518) 439-6705	Physiological & Biomedical Consulting				
INDUSTRIAL DESIGN	BioSTAR Inc. 12321 Middlebrook Rd Suite 210 Germantown, MD 20874	(301) 916-1007	Physiological & Biomedical Consulting				
INDUSTRIAL DESIGN	ECRI 5200 Butler Pike Plymouth Meeting, PA 19462	(610) 825-6000	Design Services				

Table D-1 List of Vendors Continued

VENTILATOR ITEM	VENDOR	TELEPHONE	COMPONENT	MFG	MODEL /PART NUMBER	WGT (LBS)	QTY
INDUSTRIAL DESIGN	ECRI 5200 Butler Pike Plymouth Meeting, PA 19462	(610) 825-6000	Specifications Review				
INDUSTRIAL DESIGN	ECRI 5200 Butler Pike Plymouth Meeting, PA 19462	(610) 825-6000	Equipment Selection				
INDUSTRIAL DESIGN	ECRI 5200 Butler Pike Plymouth Meeting, PA 19462	(610) 825-6000	Equipment Selection Review Meetings				
INDUSTRIAL DESIGN	ECRI 5200 Butler Pike Plymouth Meeting, PA 19462	(610) 825-6000	Prototype Development and Equipment Integrations				
INDUSTRIAL DESIGN	Electronic Prototypes Inc. 8236 Jepson Pl., Alexandria, VA 22309	(703) 799-4305	Circuitboards (Design, Develop, Fabricate)	Custom			
INDUSTRIAL DESIGN	Electronic Prototypes Inc. 8236 Jepson Pl., Alexandria, VA 22309	(703) 799-4305	Circuitboards (Design, Develop, Fabricate)	Engineering Change Orders			
INDUSTRIAL DESIGN	Novel Technologies Inc. 12321 Middlebrook Rd Germantown, MD 20874	(301) 515-6411					
INDUSTRIAL DESIGN	Paul Foster Martin 2003K Powers Ferry Rd Marietta GA 30067	(770) 984-0885					
MISCELLANEOUS	Michigan Instruments Inc. 4717 Talon Ct., S.E. Grand Rapids, MI 49512	(800) 530-9939	1 Liter Calibration Syringe				1
MISCELLANEOUS	Moore Medical Corp. 389 John Downey Dr. New Britain, CT 06050	(800) 678-8678	Breathsaver Kit Comp 1001C		34636		6
MISCELLANEOUS	Moore Medical Corp. 389 John Downey Dr. New Britain, CT 06050	(800) 678-8678	Waterjel Informational Insert		522367		1

Table D-1 List of Vendors Continued

VENTILATOR ITEM	VENDOR	TELEPHONE	COMPONENT	MFG	MODEL /PART NUMBER	WGT (LBS)	QTY
POWER, ELECTRIC	Newark Electronics 7272 Park Circle Dr Hanover, MD 21076	(410) 712-6922	Main Battery	Panasonic	LC-R122R2PU	1.83	1
POWER, ELECTRIC	Newark Electronics 7272 Park Circle Dr Hanover, MD 21076	(410) 712-6922	Backup Battery	Panasonic	LC-R121R3PU	1.18	1
POWER, ELECTRIC	Newark Electronics 7272 Park Circle Dr Hanover, MD 21076	(410) 712-6922	Power Transformer	Microtran	PL56-36	1.70	1
PUMP, INFUSION	Baxter Healthcare Corp I.V. Systems Division Route 120 & Wilson Rd Round Lake, IL 60073	(800) 933-0303	Volumteric Infusion Pump	Baxter	Flo-Gard 6201 2M8063	2.409	
PUMP, INFUSION	Baxter Healthcare Corp I.V. Systems Division Route 120 & Wilson Rd Round Lake, IL 60073	(800) 933-0303	Volumteric Infusion Pump	Baxter	2M8151 Colleague	10.4	
PUMP, MINIATURE-COMPRESSOR	Knotts Company 350 Snyder Avenue, Berkeley Heights, NJ 07922	(908) 464-4800	Rotary Pump	ASF Thomas Compressors & Vacuum Pumps 2100 Norcross Pkwy, Norcross, VA 30071 770-441-3611	G/07-30W P/N 50369	1.46	2
PUMP, MINIATURE-COMPRESSOR	ASF Thomas Compressors & Vacuum Pumps 2100 Norcross Pkwy, #120 Norcross, VA 30071	(770) 441-3611	Vacuum Pump		G/07-30W P/N 50321	1.46	
PUMP, MINIATURE-COMPRESSOR	ASF Thomas Compressors & Vacuum Pumps 2100 Norcross Pkwy, #120 Norcross, VA 30071	(770) 441-3611	Dual-Diaphragm Pump		C120CNSNF75PB 1		1
PUMP, MINIATURE-COMPRESSOR	Sensidyne Inc. 16333 Bay Vista Drive Clearwater FL 337600	(800) 451-9444	"C Series"	w/12V cordless motor			

Table D-1 List of Vendors Continued

VENTILATOR ITEM	VENDOR	TELEPHONE	COMPONENT	MFG	MODEL /PART NUMBER	WGT (LBS)	QTY
PUMP, MINIATURE-COMPRESSOR	JHU/APL		Compressor Clamps	Custom			2
PUMP, RESUSCITATION	Infusion Dynamics, Inc. 5209 Militia Hill Road Plymouth Meeting, PA 19162	(610) 941-0136	Resuscitation Pump	Infusion			1
PUMP, RESUSCITATION	Infusion Dynamics, Inc. 5209 Militia Hill Road Plymouth Meeting, PA 19162	(610) 941-0136	Power Infuser Model M100 w/remote monitoring connector	Infusion	00400-0010		2
PUMP, RESUSCITATION	Infusion Dynamics, Inc. 5209 Militia Hill Road Plymouth Meeting, PA 19162	(610) 941-0136	Single Use Sterile Cartridge, IV Set and Battery for Infuser Model M100	Infusion	0040-0050		2
PUMP, RESUSCITATION	Infusion Dynamics, Inc. 5209 Militia Hill Road Plymouth Meeting, PA 19162	(610) 941-0136	M100 Resuscitation Pump Control Unit (Version D)	Infusion	0101-0005		2
PUMP, RESUSCITATION	Infusion Dynamics, Inc. 5209 Militia Hill Road Plymouth Meeting, PA 19162	(610) 941-0136	Single Use Battery	Infusion	0101-0010		3
PUMP, RESUSCITATION	Infusion Dynamics, Inc. 5209 Militia Hill Road Plymouth Meeting, PA 19162	(610) 941-0136	Disposable Cartridge (Not Sterile)	Infusion	0101-0015		10
PUMP, RESUSCITATION	Infusion Dynamics, Inc. 5209 Militia Hill Road Plymouth Meeting, PA 19162	(610) 941-0136	External Power Supplies (Bench testing)	Infusion	0101-0020		1
VALVES	Parker Hannifin Corp Pneutronics Division 26 Clinton Dr Hollis, NH 03049	(800) 525-2857	Pneumatic Valve	Pneutronics			
VALVES	JHU/APL		Proportional Valve	Teknocraft	202611	1.67	1
VALVES	N.B. Cochrane 2900 LochRaven Road Baltimore, MD 21218	(410) 467-4884	Exhalation Valve	Peter Paul	25NK9ZGM12VDC		2

Table D-1 List of Vendors Continued

VENTILATOR ITEM	VENDOR	TELEPHONE	COMPONENT	MFG	MODEL /PART NUMBER	WGT (LBS)	QTY
VALVES	N.B. Cochrane 2900 LochRaven Road Baltimore, MD 21218	(410) 467-4884	Exhalation Valve	Peter Paul	22NK9ZGM12VDC	1.40	2
VENTILATOR	JHU/APL		Exhalation Fitting	Custom			1
VENTILATOR	Michigan Instruments Inc. 4717 Talon Ct., S.E. Grand Rapids, MI 49512	(800) 530-9939	Simulated Ventilator-Training Aid	(Phantom)	PneuView Dual Adult Model 2600i	37	1
VENTILATOR	Michigan Instruments Inc. 4717 Talon Ct., S.E. Grand Rapids, MI 49512	(800) 530-9939	Simulated Ventilator-Training Aid		PneuView AI Series (Adult/Infant)		
VENTILATOR	Oceanic Medical Products Inc. 101 S. 5th St. Suite A Atchison, KS 66002	(800) 530-9939	Pneumatically Powered Ventilation Systems				1
VENTILATOR	Pulmonetic Systems Inc. 1016 E. Cooley Drive, Suite B Colton, VA 92324	(909) 783-2280	Ventilator		AMV 2000		2

Appendix E: Software

```
THIS PROGRAM IS FOR THE MAIN uP IN THE RESPIRATOR SUBSYSTEM MOCKUP
    ; TITLE ON DISK:     FLOWFIN1.ASM
    ; TEST PROGRAM REALITY2: 1) TESTS RELAYS
    ;                        2) TESTS VOLTAGE OUTPUT FOR VALVE
    ;                        3) TESTS TIMER INTERUPTS
    ;                        4) SHOWS CALCULATED NUMBER OF TIME INTERVALS
    ;
    ; PROGRAM CREATED: TUE 6/23/98 for Motorola 69HC811 Microprocessor
    ; THIS REVISION DATED: FRI 8/7/98  3:50 AM
    ; CHANGES
    ;  1) READ LOCK/UNLOCK SWITCH TO SET INITIAL MODE
                DEFSEG          PTS, START=0F800H
                SEG PTS
                GLOBAL          SYEXEC
                GLOBAL          PORTAADR,PORTBADR,PORTCADR,PORTDADR
                GLOBAL          BAUD,SCCR2,SCCR1,SCDR,SCSR
                GLOBAL          OPTION,ADR1,ADCTL,MODE
                ORG             0FFFEH          ;RESET ADDRESS
                FDB             SYEXEC
                ORG             0FFF8H          ;ILLEGAL OPCODE TRAP
                FDB             SYEXEC          ;SET TO RESET ADDRESS
                ORG             0FFE8H          ;TIMER OUTPUT COMP 1
                FDB             EXPIRE2         ;STAR EXPIRATION
                ORG             0FFE6H          ;TIMER OUTPUT COMP 2
                FDB             INSPIRE
                ORG             0FFF6H          ;SOFTWARE INTERUPT
                FDB             INSPIRE         ;TO START CYCLE
;------------------------------------------------------------------------
;RAM ADDRESSES
; VARIABLE          REL. ADD.     ABS. ADD. FUNCTION
DURATION     EQU    $0000         ; 0       HIGH LEVEL DURATION
WIDTHSET     EQU    DURATION+1    ; 1       PULSE WIDTH SETTING
WIDTHSECD    EQU    WIDTHSET+1    ; 2       SPACE HOLDER FOR DOUBLE BYTE
WIDTHSEC     EQU    WIDTHSECD+1   ; 3&4     ACTUAL PULSE WIDTH (mS)
MAXPRESS     EQU    WIDTHSEC+2    ; 5       MAX PRESSURE 10-40mmHg
ITOERAW      EQU    MAXPRESS+1    ; 6       RAW I:E READING OFF POT
TIDALVOL     EQU    ITOERAW+1     ; 7&8     200-600
RATEPERMIN   EQU    TIDALVOL+2    ; 9       8-20 BREATHS PER MINUTE
CALCOMP      EQU    RATEPERMIN+1  ; 10      CALIBRATION COMPLETE FLAG
MODE         EQU    CALCOMP+1     ; 11      MODE SWITCH SETTING (0-4)
ZEROPRESS    EQU    MODE+1        ; 12&13   PRESSURE ZERO CALIBRATION
ZEROFLOW     EQU    ZEROPRESS+2   ; 14&15   AIR FLOW ZERO CALIBRATION
TOTALTIME    EQU    ZEROFLOW+2    ; 16&17   TOTAL CYCLE TIME 3,000 TO 7,500
INSPTIME     EQU    TOTALTIME+2   ; 18&19   INSPIRATORY TIME 1,50 TO 5,625
EXPTIME      EQU    INSPTIME+2    ; 20&21   EXPIRATORY TIME 750 TO 3,750
TOTALCOUNT   EQU    EXPTIME+2     ; 22&23   NUMBER OF 10 msec PERIODS TOTAL
INSPCOUNT    EQU    TOTALCOUNT+2  ; 24&25   NUMBER OF 10msec PERIODS FOR INSP
EXPCOUNT     EQU    INSPCOUNT+2   ; 26&27   NUMBER OF 10msec PERIODS FOR EXP
CURRCOUNT    EQU    EXPCOUNT+2    ; 28&29   CURRENT COUNT
ITOEACTUAL   EQU    CURRCOUNT+2   ; 30&31   ACTUAL I:E X 10
TEMP1        EQU    ITOEACTUAL+2  ; 32&33   TEMPORARY STORAGE LOCATION
FLOWTARGET   EQU    TEMP1+2       ; 34&35   DESIRED AVERAGE AIR FLOW RATE
VALVESET     EQU    FLOWTARGET+2  ; 36&37   VALVE SETTING (0-255 DOUBLE)
THREEDIG     EQU    VALVESET+2    ; 38&39   THREE DIGIT NUMBER TO WRITE
TWODIG       EQU    THREEDIG+2    ; 40      TWO DIGIT NUMBER TO WRITE
REMAINDER    EQU    TWODIG+1      ; 41&42   REMAINDER
BLANKFLAG    EQU    REMAINDER+2   ; 43      FLAG FOR BLANKS
RUNSTOP      EQU    BLANKFLAG+1   ; 44      RUN=1 STOP=0
DISPMODEFLG  EQU    RUNSTOP+1     ; 45      DISPLAY MODE BUTTON POSITION 1=DEP
```

```
LOCKSTATUS    EQU   DISPMODEFLG+1 ;46     STATUS OF LOCK/UNLOCK SWITCH
FLOWRAW       EQU   LOCKSTATUS+1 ;47&48   RAW VALUE (0-255) OF FLOW
INTEGVOL      EQU   FLOWRAW+2     ;49&50  INTEGRATED VOLUME THIS CYCLE
CURRFLOW      EQU   INTEGVOL+2    ;51&52  CURRENT FLOW (ml/sec)
GETMODE       EQU   CURRFLOW+2    ;53     0-3 PARAMETER TO BE DISPLAYED
TIDALVOL2     EQU   GETMODE+1     ;54&55  TIDAL VOLUME X 50
TIMEREMAIN    EQU   TIDALVOL+2    ;56&57  REMAINING INSPIRATION TIME
RAWPRESS      EQU   TIMEREMAIN+2 ;58&59   RAW (0-255) PRESSURE READING
ACTUPRES      EQU   RAWPRESS+2    ;60&61  ACTUAL PRESSURE (mmHg)
RAWPRESLIM    EQU   ACTUPRES+2    ;62&63  RAW PRESSURE LIMIT
;------------------------------------------------------------------------
;ROM ADDRESES (REGISTERS ETC.)
BAUD             EQU             $102B
SCCR1            EQU             $102C
SCCR2            EQU             $102D
SCSR             EQU             $102E
SCDR             EQU             $102F
PORTAADR         EQU             $1000
PORTBADR         EQU             $1004
PORTCADR         EQU             $1003
PORTDADR         EQU             $1008
DDRC             EQU             $1007
DDRD             EQU             $1009
PACTL            EQU             $1026
TCNT             EQU             $100E
TIC1             EQU             $1010
TOC1             EQU             $1016
TOC2             EQU             $1018
TCTL2            EQU             $1021
TFLG1            EQU             $1023
TMSK1            EQU             $1022
TMSK2            EQU             $1024
ADCTL            EQU             $1030
ADR1             EQU             $1031
ADR2             EQU             $1032
ADR3             EQU             $1033
OPTION           EQU             $1039
;--------------------------------------------------------------------------
                 ORG             0F800H
SYEXEC           EQU             $
                 SEI                                 ;DISABLE INTERRUPTS
                 LDS             #00FFH
                 LDAA            #00000011B          ;SET COUNT RATE TO E/16
                 STAA            TMSK2               ;WITHIN FIRST 64 CLK CYCLES
                 CLR             CALCOMP             ;POWER-UP UNCALIBRATED
                 LDAA            #11111111B          ;CONFIG PORT C AS ALL
                 STAA            DDRC                ;OUTPUT FOR D/A INTERFACE
                 LDAA            #00001100B          ;CONFIG PORT D BITS 2&3 AS
OUT
                 STAA            DDRD
                 LDAA            OPTION
                 ORAA            #11100000B          ;TURN ON A/D POWER & CLK
                 STAA            OPTION
                 CLR             GETMODE
                 CLR             MODE
                 CLR             RUNSTOP
                 CLR             LOCKSTATUS
                 CLR             PORTCADR            ;SHUT OFF FLOW SOLENOID
                 LDAA            PACTL
```

```
            ORAA      #00001000B     ;CONFIG PTA BIT 3 AS OUT
            STAA      PACTL
            CLR       PORTAADR
            LDD       #0
            STD       INTEGVOL
            LDAA      #25            ;DEFAULT MAX PRESSURE
            STAA      MAXPRESS       ;SET TO 25 mmHg
            LDAA      #14            ;DEFAULT RATE=
            STAA      RATEPERMIN     ;14 BREATHS PER MINUTE
            LDAA      #20            ;DEFAULT I:E= 1:2.0
            STAA      ITOERAW
            JSR       HALFSEC        ;LCD POWER UP DELAY
TRYCAL      JSR       LCDINIT
            LDX       #FFCCU         ;WRITE SOFTWARE VERSION
            LDY       #16
            JSR       LCDWRITE
            JSR       LCDCONT
            LDAA      #0C0H
            JSR       STROBEN
            JSR       CHARWRIT
            LDX       #VERSION
            LDY       #16
            JSR       LCDWRITE
            LDAA      #6
MOREDISP1   JSR       HALFSEC
            DECA
            BNE       MOREDISP1
TERM2       LDAB      #092H          ;CURSOR TO MODE
            JSR       SETCURSOR      ;TEXT LOCATION
            LDX       #STOP1
            LDY       #4
            JSR       LCDWRITE
            LDAA      PORTDADR       ;CHECK LOCK/UNLOCK SWITCH
            ANDA      #00010000B
            BNE       UNLOCKIT
            BRA       ISOK1
UNLOCKIT    JSR       LCDINIT
            LDX       #PUSHLOCK      ;WRITE "PUSH LOCK/"
            LDY       #10
            JSR       LCDWRITE
            LDX       #UNLOCK        ;WRITE "UNLOCK SWITCH"
            LDY       #13
            JSR       LCDWRITE
CHKSWITCH2  LDAA      PORTDADR
            ANDA      #00010000B
            BNE       CHKSWITCH2
ISOK1       JSR       LCDINIT
            LDX       #CALIB         ;WRITE "CALIBRATING"
            LDY       #11
            JSR       LCDWRITE
            LDAB      #0C0H
            JSR       SETCURSOR
            LDX       #ZEROES
            LDY       #10
            JSR       LCDWRITE
            LDAB      #0C3H
            JSR       SETCURSOR
            LDAA      #00000100B     ;PE4=PRESSURE
            JSR       GETDATA        ;SELECT PRESSURE INPUT
```

```
                TAB
                LDAA        #0
                STD         ZEROPRESS       ;STORE ZERO
                STD         THREEDIG
                JSR         WRITTHREE
                LDAB        #0CAH
                JSR         SETCURSOR
                LDAA        #00000111B      ;PE7=FLOW
                JSR         GETDATA
                TAB
                LDAA        #0
                STD         ZEROFLOW
                STD         THREEDIG
                JSR         WRITTHREE
                LDAA        #6
MORECAL         JSR         HALFSEC
                DECA
                BNE         MORECAL
AFTERTERM       JSR         SETPARAM
                BRA         AFTERTERM2
AFTERTERM1      JSR         SENSEWRITE
AFTERTERM2      JSR         CHECKSWITCH
                LDAA        RUNSTOP
                BEQ         ONEMORE
                JMP         STARTVENT
ONEMORE         LDAA        LOCKSTATUS
                BEQ         AFTERTERM2
                BRA         AFTERTERM1
;-------------------------------------------------------------------------
MEASPRES        LDAA        #00000100B      ;PE4=FLOW
                JSR         GETDATA
                TAB
                LDAA        #0
                STD         RAWPRESS        ;STORE RAW PRESSURE
                RTS
;-------------------------------------------------------------------------
WRITEPRESS      LDAB        #085H
                JSR         SETCURSOR
                LDD         RAWPRESS
                STD         THREEDIG
                JSR         WRITTHREE
                LDAB        #0C0H
                JSR         SETCURSOR
                LDD         ZEROPRESS
                STD         THREEDIG
                JSR         WRITTHREE
                LDAB        #08BH
                JSR         SETCURSOR
                LDD         RAWPRESS        ;0-255
                SUBD        ZEROPRESS       ;SUBTRACT ATMOSPHERIC
                LSRB                        ;DIVIDE BY 2
                LDAA        #6              ;0-127
                MUL                         ;0-762
                LDX         #10             ;0-76
                IDIV
                XGDX
                STD         ACTUPRES
                STD         THREEDIG
                JSR         WRITTHREE
```

```
            JSR         HALFSEC
            RTS
;-------------------------------------------------------------------
CHECKSWITCH LDAA        PORTDADR        ;CHECK LOCK/UNLOCK
            ANDA        #00010000B
            BEQ         CHECKRUN
            LDAA        #1
            STAA        LOCKSTATUS
            BRA         CHECKRUN2
CHECKRUN    CLR         LOCKSTATUS
CHECKRUN2   LDAA        PORTAADR        ;CHECK RUN/STOP
            ANDA        #00000010B
            BEQ         CHECKDISP
            LDAA        #1
            STAA        RUNSTOP
            BRA         CHECKDISP2
CHECKDISP   CLR         RUNSTOP
CHECKDISP2  LDAA        PORTAADR
            ANDA        #00000100B      ;GET DISPLAY MODE SWITCH
            BEQ         LASTSWITCH
            LDAA        #1
            STAA        DISPMODEFLG
            BRA         LASTSWITCH2
LASTSWITCH  CLR         DISPMODEFLG
LASTSWITCH2 RTS
;-------------------------------------------------------------------
SETPARAM    JSR         LCDINIT
            LDX         #LINE1
            LDY         #12
            JSR         LCDWRITE
            JSR         LCDCONT
            LDAB        #0C0H           ;SECOND LINE OF TEXT
            JSR         SETCURSOR
            LDX         #LINE2
            LDY         #24
            JSR         LCDWRITE
SENSEWRITE  LDAA        GETMODE
            CMPA        #0
            BNE         NEXTGET1
            JSR         GETRATE
            BRA         INCGET
NEXTGET1    CMPA        #1
            BNE         NEXTGET2
            JSR         NEXTPARAM1
            BRA         INCGET
NEXTGET2    CMPA        #2
            BNE         DOTHELAST
            JSR         WRITEMAXP
            BRA         INCGET
DOTHELAST   JSR         WRITETV
INCGET      INC         GETMODE
            LDAA        GETMODE
            CMPA        #4
            BEQ         RESETGET
            RTS
RESETGET    CLR         GETMODE
            RTS
;-------------------------------------------------------------------
```

```
GETRATE     LDAA    #00000000B    ;SELECT CHANNEL ZERO=RATE
            JSR     GETDATA
            TAB                   ;MAKE 16 BITS
            CLRA
            LDX     #20           ;255/20=12 MAX
            IDIV
            XGDX                  ;GET RESULT INTO D REG
            ADDB    #8            ;8=MINIMUM RATE
            STAB    RATEPERMIN    ;STORE RATE
            STAB    TWODIG
            JSR     LCDCONT
            LDAB    #085H         ;RATE LOCATION
            JSR     SETCURSOR
            JSR     WRITTWO
            RTS
;------------------------------------------------------------------
NEXTPARAM1  JSR     LCDCONT
            LDAB    #8CH          ;I:E DATA LOCATION
            JSR     SETCURSOR
            LDAA    #31H          ;WRITE A "1"
            JSR     STROBEN
            LDAA    #3AH          ;":"
            JSR     STROBEN
            LDAA    #00000001B    ;SELECT CHANNEL 1=I:E
            JSR     GETDATA
            STAA    ITOERAW
            TAB
            CLRA
            LDX     #13
            IDIV
            XGDX                  ;RESULT=0 TO 19
            ADDB    #10           ;RESULT=10 TO 29
            STAB    ITOEACTUAL
            LDX     #10
            IDIV                  ;RESULT = 1 OR 2
            XGDX
            ADDB    #30H
            TBA
            JSR     STROBEN
            LDAA    #2EH          ;DECIMAL POINT
            JSR     STROBEN
            XGDX
            ADDB    #30H
            TBA
            JSR     STROBEN
            LDAB    #092H          ;CURSOR TO MODE
            JSR     SETCURSOR      ;TEXT LOCATION
            LDAA    RUNSTOP
            BEQ     WRITSTOP
            LDX     #RUN1
            LDY     #4
            JSR     LCDWRITE
            BRA     FINAL1
WRITSTOP    LDX     #STOP1
            LDY     #4
            JSR     LCDWRITE
FINAL1      JSR     INITCALC      ;CALCULATE INSPCOUNT
            RTS
;__________________________________________________________________
```

```
WRITEMAXP       JSR     LCDCONT
                LDAB    #0C8H           ;LOCATION OF MAX PRESS
                JSR     SETCURSOR
                LDAA    #00000010B      ;CHANNEL 2=MAXPRESS
                JSR     GETDATA
                LDAB    #2              ;NEED TO DIVIDE BY 8.5
                MUL                     ;SO MUL BY 2 & DIV BY 17
                LDX     #17
                IDIV                    ;RESULT I X=0-30
                XGDX                    ;RESULT IN D
                ADDB    #10             ;B REG= 10 TO 40
                STAB    MAXPRESS
                STAB    TWODIG
                JSR     WRITTWO
                LDAB    MAXPRESS        ;10-40
                LDAA    #10
                MUL                     ;100-400
                LDX     #6
                IDIV                    ;16-66
                XGDX                    ;RESULT INTO D REG
                LSLD                    ;X2=32-132
                ADDD    ZEROPRESS
                STD     RAWPRESLIM
                RTS
;______________________________________________________________________
WRITETV         JSR     LCDCONT
                LDAB    #0D2H           ;CURSOR LOC. FOR TV
                JSR     SETCURSOR
                LDAA    #00000101B      ;CHANNEL 5 = TV
                JSR     GETDATA
                TAB
                CLRA
                LDX     #6
                IDIV                    ;RESULT IN D=0 TO 42
                XGDX                    ;RESULT IN D (B =LOW)
                LDAA    #10
                MUL                     ;D=0 TO 420 ml
                ADDD    #200            ;MINIMUM TV=200ml
                STD     TIDALVOL
                LDD     INSPCOUNT       ;MAX=371 MIN=71
                SUBD    #1              ;MAX=370 MIN=70
                STD     TEMP1           ;MULTIPLY BY 24
                LDX     #23             ;MAX VALUE=8,880
MORETV          ADDD    TEMP1
                DEX
                BNE     MORETV
                LDX     #10
                IDIV
                XGDX                    ;RESULT IN D
                CPD     TIDALVOL
                BLT     SWAPTV
                BRA     WRITTV
SWAPTV          STD     TIDALVOL        ;STORE DIMINISHED TV
WRITTV          LDD     TIDALVOL
                STD     THREEDIG
                JSR     WRITTHREE
                RTS
;----------------------------------------------------------------------
```

```
;THE FOLLOWING SECTION CALCULATES THE VARIABLES NEEDED FOR RESPIRATION
INITCALC        LDAB            RATEPERMIN      ;8-20
                CLRA
                XGDX
                LDD             #6000
                IDIV                            ;RESULT=300 TO 750
                STX             TOTALCOUNT
                LDAB            ITOEACTUAL      ;10 TO 29
                ADDB            #10             ;20 TO 39
                CLRA
                XGDX
                LDD             TOTALCOUNT      ;300 TO 750
                IDIV                            ;7 TO 37
                XGDX
                LDAA            #10
                MUL                             ;RESULT=70 TO 370
                ADDD            #1              ;1 EXTRA
                STD             INSPCOUNT
                LDD             TOTALCOUNT
                SUBD            INSPCOUNT       ;RANGE=75 TO 375
                ADDD            #2              ;ACTUALLY 1 EXTRA
                STD             EXPCOUNT        ;RANGE=150 TO 562
                LDD             #0
                STD             CURRCOUNT       ;ZERO CURRCOUNT
                LDD             TIDALVOL
                LDX             #49
ADDTIDAL        ADDD            TIDALVOL        ;MULTIPLY TV X 50
                DEX
                BNE             ADDTIDAL
                STD             TIDALVOL2
                RTS
;-----------------------------------------------------------------------
;THE FOLLOWING CRITICAL SECTION CALCULATES THE DESIRED AIR FLOW
SETFLOW1        LDD             TIDALVOL        ;200-600
                LDX             #INSPCOUNT
STARTVENT       LDAB            #092H           ;CURSOR TO MODE
                JSR             SETCURSOR       ;TEXT LOCATION
                LDX             #RUN1
                LDY             #4
                JSR             LCDWRITE
                CLI                             ;CLEAR INTERUPTS
                LDAA            PORTDADR
                ORAA            #00001000B      ;TURN ON COMPRESSOR
                STAA            PORTDADR
                JSR             HALFSEC         ;DELAY FOR IN-RUSH
                JSR             HALFSEC         ;CURRENT
                LDAA            #01000000B      ;ENABLE OC2 INT
                STAA            TMSK1
                SWI                             ;START VENTILLATING
WAITAGAIN       JSR             MEASPRES
                LDD             RAWPRESS
                CPD             RAWPRESLIM
                BLE             MAINLOOP1
                JSR             ENDINSP
MAINLOOP1       WAI
                CLI
                BRA             WAITAGAIN
```

```
;TIMING VARIABLES NOW SET
;---------------------------------------------------------------
INSPIRE         LDD         TCNT            ;SET COMPARE REGISTER
                ADDD        #625            ;10 msec INTERVAL
                STD         TOC2
                LDAA        #11111111B      ;CLEAR TIMER INT FLAGS
                STAA        TFLG1
                JSR         SETVALVE
                LDD         CURRCOUNT
                ADDD        #1
                STD         CURRCOUNT
                CPD         INSPCOUNT
                BNE         GOON617
                JSR         ENDINSP
                RTI
;-----------------------------------------------------------------
ENDINSP         LDD         #0              ;SHUT DOWN INSPIRE
                STD         CURRCOUNT
                STD         INTEGVOL        ;RESET INTEGRATED VOL
                LDAA        #10000000B      ;ENABLE OC1
                STAA        TMSK1
                LDAA        PORTDADR
                ANDA        #11111011B      ;CLOSE EXP VALVE
                STAA        PORTDADR
                RTS
;-----------------------------------------------------------------
GOON617         LDD         CURRFLOW        ;CURRFLOW ALREADY MEAS.
                LSRD                        ;DIVIDE BY 2
                ADDD        INTEGVOL        ;50 X ACTUAL VOLUME
                STD         INTEGVOL
                CPD         TIDALVOL2       ;COMPARE TO 50X TIDAL
                BGE         ENDINSP         ;END INSPIRATION IF>=
                LDAA        PORTAADR        ;CHECK RUN SWITCH
                ANDA        #00000010B
                BNE         RETURN1
                JSR         TERMINATE
                LDS         #00FFH          ;RELOAD STACK POINTER
                JMP         AFTERTERM
RETURN1         RTI
;---------------------------------------------------------------
TERMINATE       CLR         TMSK1
                LDAA        PORTDADR
                ANDA        #11110111B      ;TURN OFF COMPRESSOR
                STAA        PORTDADR

                LDAA        #6
MOROFFDEL       JSR         HALFSEC
                DECA
                BNE         MOROFFDEL
                LDAA        PORTDADR
                ANDA        #11111011B      ;CLOSE EXP VALVE
                STAA        PORTDADR
                RTS
;--------------------------------------------------------------------
EXPIRE2         LDD         TCNT
                ADDD        #625
                STD         TOC1
```

```
                LDAA            #11111111B      ;CLEAR TIMER INT FLAGS
                STAA            TFLG1
                LDD             CURRCOUNT
                ADDD            #1
                STD             CURRCOUNT
                CPD             EXPCOUNT
                BNE             GOON6172
                LDD             #0
                STD             CURRCOUNT
                CLR             TMSK1           ;DISABLE TIMER INT
                LDAA            #01000000B      ;ENABLE OC2 INT
                STAA            TMSK1
                LDAA            #0
                STAA            PORTCADR        ;SHUT OFF OUTPUT VALVE
                LDAA            PORTDADR
                ORAA            #00000100B      ;OPEN EXHALATION VALVE
                STAA            PORTDADR
GOON6172        RTI
;---------------------------------------------------------------------
MEASFLOW        LDAA            #00000111B      ;PE7=FLOW CHANNEL
                JSR             GETDATA
                TAB                             ;INITIAL VALUE=0-255
                LDAA            #0
                SUBD            ZEROFLOW        ;LESS OFFSET (0-210)
                STD             TEMP1           ;MULTIPLY BY 83
                LDX             #82
SUMFLOW         ADDD            TEMP1           ;83 (ml/sec)/volt
                DEX
                BNE             SUMFLOW
                LDX             #51             ;51 A/D counts/volt
                IDIV
                XGDX
                STD             CURRFLOW        ;RESULT=0-240ml/sec
                RTS
;---------------------------------------------------------------------
;THE FOLLOWING SUBROUTINE SETS THE VALVE TO OBTAIN A FLOW RATE SET
;INTO THE VARIABLE FLOWTARGET (0-255 IN D DOUBLE REG)
SETVALVE        LDD             CURRCOUNT
                BNE             SETVALVE1
                LDD             #127            ;ALWAYS START AT 127
                BRA             ENDSETVALVE
SETVALVE1       LDD             VALVESET
                ADDD            #5
                CPD             #255
                BGE             SETMAX1
                BRA             SETIT
SETMAX1         LDD             #255
SETIT           STD             VALVESET
                STAB            PORTCADR
                RTS
SETVALVEX       JSR             MEASFLOW
                LDD             INSPCOUNT       ;TOTAL 10ms INSP. INTERV.
                SUBD            #1              ;1 EXTRA IN TIMING
                SUBD            CURRCOUNT       ;SUBTRACT NUMBER SO FAR
                STD             TIMEREMAIN      ;NUMBER REMAINING
                LDD             TIDALVOL2       ;LOAD TIDALVOL X 50
                SUBD            INTEGVOL        ;SUBTRACT VOL ALREADY
```

```
                LDX         TIMEREMAIN
                IDIV
                XGDX                        ;RESULT INTO D REG
                LSLD                        ;MUL BY 2(VOLX50)/(TIM*100)
                SUBD        CURRFLOW        ;IN ml/sec (0-240)
                CPD         #10
                BGT         REDUCFLO
                CPD         #-10
                BLT         INCFLOW
                RTS
REDUCFLO        LDD         VALVESET
                SUBD        #8
                CPD         #0
                BLT         SET0
                BRA         ENDSETVALVE     ;NO ROLL UNDER
SET0            LDD         #0
                BRA         ENDSETVALVE
INCFLOW         LDD         VALVESET
                ADDD        #8              ;127+(16*8)=255
                CPD         #255
                BGT         SET255          ;NO ROLL OVER
                BRA         ENDSETVALVE
SET255          LDD         #255
ENDSETVALVE     STD         VALVESET
                STAB        PORTCADR
                LDD         CURRFLOW        ;(0-240)
                LSRB                        ;DIVIDE BY 2
                ADDD        INTEGVOL
                STD         INTEGVOL
                RTS
;------------------------------------------------------------------
;THIS ROUTINE MOVES CURSOR TO LOCATION PREVIOUS STORED IN B REGISTER
SETCURSOR       JSR         LCDCONT
                TBA
                JSR         STROBEN
                JSR         CHARWRIT
                RTS
;------------------------------------------------------------------
WRITTHREE       CLR         BLANKFLAG
                LDD         THREEDIG        ;LOAD VARIABLE
                LDX         #100
                IDIV
                XGDX
                TBA
                BNE         DIG31
                JSR         WRITBLANK
                LDAA        #1
                STAA        BLANKFLAG
                BRA         TVDIG2
DIG31           ADDA        #30H
                JSR         STROBEN
TVDIG2          XGDX                        ;GET REMAINDER INTO D
                LDX         #10
                IDIV
                XGDX                        ;RESULT INTO D REG
                TBA
                BNE         DIG32
```

```
                LDAB        BLANKFLAG       ;=1 IF DIGIT 1=BLANK
                BEQ         DIG32           ;IF 0 WRITE A ZERO
                JSR         WRITBLANK       ;ELSE, WRITE ANOTHER BLNK
                BRA         TVDIG3
DIG32           ADDA        #30H
                JSR         STROBEN
TVDIG3          XGDX
                TBA
                ADDA        #30H
                JSR         STROBEN
                RTS
;------------------------------------------------------------------
WRITTWO         LDAB        TWODIG          ;LOAD VARIABLE
                LDAA        #0
                LDX         #10
                IDIV
                XGDX
                TBA
                BNE         DIG21
                JSR         WRITBLANK
                BRA         TWODIG2
DIG21           ADDA        #30H
                JSR         STROBEN
TWODIG2         XGDX                        ;GET REMAINDER INTO D
                TBA
                ADDA        #30H
                JSR         STROBEN
                RTS
;------------------------------------------------------------------
WRITBLANK       LDAA        #20H
                JSR         STROBEN
                RTS
;------------------------------------------------------------------
LCDWRITE        SEI
                LDAB        PORTAADR
                ORAB        #00001000B      ;SET RS TO ONE TO WRITE
                STAB        PORTAADR
NEXTCHAR        LDAA        0,X             ;LOAD NEXT CHARACTER TO
                JSR         STROBEN
                DEY
                BEQ         DONEWRIT
                INX
                BRA         NEXTCHAR
DONEWRIT        RTS
;------------------------------------------------------------------
HALFSEC         LDY         #0003H          ;0.5 SECOND ON DELAY
NEXT11          LDX         #06D66H         ;6D66=28,006
NEXT10          DEX                         ;DEX=3 CYCLES
                BNE         NEXT10          ;DNE=3 CYCLES
                DEY
                BNE         NEXT11
                RTS
;------------------------------------------------------------------
QUARTSEC        LDY         #0003H          ;0.225 SECOND DELAY
NEXT12          LDX         #0313BH
NEXT13          DEX
                BNE         NEXT13
```

```
            DEY
            BNE         NEXT12
            RTS
;-----------------------------------------------------------------
MSDELAY4    LDX         #428          ;9 CYCLES/LOOP
COMP        DEX                       ;9X428=3852microsec
            BNE         COMP
ENDDELAY    RTS
;-----------------------------------------------------------------
MSDELAY50   LDX         #5556         ;9 CYCLES/LOOP
COMP9       DEX                       ;9X5556=50,004microsec
            BNE         COMP9
ENDDELAY2   RTS
;-----------------------------------------------------------------
LCDINIT     JSR         LCDCONT
            LDAA        #$01          ;CLEAR DISPLAY
            JSR         STROBEN
            JSR         MSDELAY4      ;4MSEC FOR DISPLAY
            LDAA        #$02          ;SEND CURSOR HOME
            JSR         STROBEN
            JSR         MSDELAY4      ;4MSEC FOR DISPLAY
            LDAA        #$38          ;CONFIG FOR 2 LINES &
            JSR         STROBEN       ;8 BIT INTERFACE, 5X7
            LDAA        #$06          ;CURSOR SHIFT WITH WRITE
            JSR         STROBEN
            LDAA        #$0C          ;CURSOR OFF & DISPLAY ON
            JSR         STROBEN
            RTS
;-----------------------------------------------------------------
LCDCONT     LDAA        PORTAADR
            ANDA        #11000111B    ;ZERO R/W,E,AND RS LINES
            STAA        PORTAADR
            RTS
;-----------------------------------------------------------------
STROBEN     STAA        PORTBADR      ;SET DATA LINES
            LDAA        PORTAADR
            ORAA        #00100000B    ;SET ENABLE TO ONE
            STAA        PORTAADR
            ANDA        #11011111B    ;SET ENABLE LOW
            STAA        PORTAADR
            LDAA        #5            ;40 MICROSECOND DELAY
MORDEL1     DECA                      ;FOR EACH CHARACTER
            BNE         MORDEL1       ;5 PASSES X 8 CYCLES
DONESTROB   RTS
;-----------------------------------------------------------------
GETDATA     STAA        ADCTL         ;SELECT ANALOG CHANNEL
NEXT2       LDAA        ADCTL
            ANDA        #10000000B
            BNE         TAKSAMP1      ;CHECK FOR CONVERSION
            BRA         NEXT2         ;COMPLETE
TAKSAMP1    LDAA        ADR1
            RTS
;-----------------------------------------------------------------
ASCII       ADDA        #30H
            JSR         STROBEN
            RTS
;-----------------------------------------------------------------
```

```
CHARWRIT        LDAA        PORTAADR        ;SET RS TO 1
                ORAA        #00001000B
                STAA        PORTAADR
                RTS
;---------------------------------------------------------------------------
;TEXT DATA STORAGE FOR LCD DISPLAY AND LOOK-UP TABLES
;LINE1 TEXT
;-----------------------------------------------------------------------------
ZEROES   FCB 50H,30H,3DH,20H,20H,20H,20H,46H,30H,3DH       ;P0=____F0=(10)
INSPTEXT FCB 49H,4EH,43H,4EH,54H,3DH                       ;INCNT=(6)
EXPTEXT  FCB 45H,58H,43H,4EH,54H,3DH                       ;EXCNT=(6)
RUN1     FCB 52H,55H,4EH,20H                               ;RUN (4)
STOP1    FCB 53H,54H,4FH,50H                               ;STOP (4)
LINE1    FCB 52H,41H,54H,45H,3DH,20H,20H,20H               ;RATE=___(8)
LINE1B   FCB 49H,3AH,45H,3DH                               ;I:E=    (4)
LINE2    FCB 4DH,41H,58H,50H,52H,45H,53H,3DH,20H,20H       ;MAXPRES=__(10)
LINE2B   FCB 6DH,6DH,48H,67H,20H                           ;mmhg_   (5)
LINE2C   FCB 54H,56H,3DH,20H,20H,20H,20H,6DH,6CH           ;TV=____ml(9)
FFCCU    FCB 46H,46H,43H,43H,55H,20H                       ;FFCCU_  (6)
         FCB 50H,52H,4FH,54H,4FH,54H,59H,50H,45H           ;PROTOTYPE (9)
VERSION  FCB 56H,45H,52H,53H,49H,4FH,4EH,20H               ;VERSION_(8)
         FCB 46H,4CH,4FH,57H,46H,49H,4EH,31H               ;FLOWFIN1 (8)
HIGH     FCB 48H,49H,47H,48H                               ;HIGH (4)
PUSHLOCK FCB 50H,55H,53H,48H,20H,4CH,4FH,43H,4BH,2FH         ;PUSH LOCK/ (10)
CALIB    FCB 43H,41H,4CH,49H,42H,52H,41H,54H,49H,4EH,47H     ;CALIBRATING(11)
UNLOCK   FCB 55H,4EH,4CH,4FH,43H,4BH                         ;UNLOCK     (6)
SWITCH   FCB 20H,53H,57H,49H,54H,43H,48H                     ;_SWITCH    (7)
FLOWTXT  FCB 46H,4CH,4FH,57H,3DH,20H,20H,20H,63H,63H   ;FLOW=___cc/sec(10)
         FCB 2FH,73H,65H,63H,20H,52H,41H,57H,3DH       ;RAW= (9)
VALVE    FCB 56H,41H,4CH,56H,45H,3DH                   ;VALVE=
;-----------------------------------------------------------------------------
                END
```

8 Glossary

ACTD	Advanced Concept Technology Demonstration
A/D	Analog-to-Digital
ADM	Advanced Development Model
ASIC	Application Specific Integrated Circuit
ATA	Army Technical Architecture
BP	Blood Pressure
CASB	Cost Accounting Standards Board
CDR	Critical Design Review
CD-ROM	Compact Disk Read Only Memory
CECOM	Communications-Electronics Command
CPN	Capnograph
D/A	Digital-to-Analog
DCAA	Defense Contract Audit Agency
DOE	Department of Energy
ECG	Electrocardiograph
EEPROM	Electrically Erasable Programmable Read Only Memory
EMI	Electromagnetic Interference
FDA	Federal Drug Administration
FEMA	Federal Emergency Management Association
FFLSS	Far Forward Life Support System
IV	Intravenous
JHU/APL	The Johns Hopkins University Applied Physics Laboratory
LCD	Liquid Crystal Display
LSTAT	Life Support for Trauma and Transport
MTA	Materials Transfer Agreement
NBC	Nuclear / Biological / Chemical
OEM	Original Equipment Manufacturer
PDR	Preliminary Design Review
ROM	Read Only Memory
UARC	University Affiliated Research Center
VHSIC	Very High Speed Integrated Circuit
VLSI	Very Large Scale Integration